

Analysis of Long-term Freight Transport, Logistics and Related CO₂ Trends on a Business-as-Usual Basis

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Abstract

Freight transport is the life-blood of today's economy. Raw materials, components and finished products flow in vast quantities through complex supply chain systems to satisfy the demands of the ultimate customers. Although vital to ensure economic prosperity, freight transport also poses a large burden on the environment and society. Road remains a dominant mode of freight transport in the UK, with 65% of the total tonne-kms moved and 82% of tonnes lifted in 2008. Most of the externalities associated with road freight transport have already been subject to legal environmental controls. CO₂ emissions are the only externality that still remains unregulated.

In order to evaluate the effects of potential regulations or other policy options, decision makers need a reliable forecast of the future course of the road freight transport- related CO₂ emissions in the absence of such new initiatives and interventions. Most currently available forecasts relate to road transport as a whole and focus on the passenger vehicle activity. Forecasts of road freight volumes and related externalities are typically linked to trends in economic activity, ignoring changes in the nature of logistics and supply chain systems. Hence, the aim of this thesis is to produce a forecast of road freight transport – related CO₂ emissions up to 2020 on a business-as-usual (BAU) basis by incorporating the projections on future trends in a number of logistics and road freight transport variables and the driving forces behind them.

The theoretical foundations of the logistics and supply chain management discipline continuously evolve, allowing researchers to view real-world problems from an array of philosophical perspectives, leading to scientific advancement and enrichment of the body of knowledge. This thesis is rooted in the critical realist paradigm and employs methodological triangulation involving focus group research, a Delphi questionnaire survey and spreadsheet modelling to produce a reliable BAU forecast of future CO₂ emissions from road freight transport.

In addition to the forecast of future CO₂ emissions from Heavy Goods Vehicles, this research also elicits forecasts of changes in key logistics and freight transport variables such as handling factor, average length of haul, modal split, empty running, lading factor and fuel efficiency up to 2020. The main structural, commercial, operational, functional, external and product-related factors behind future trends in these variables are also investigated. The BAU scenario is assessed in the light of the UK greenhouse gas reduction target and additional scenarios offering CO₂ savings greater than that predicted by the BAU case modelled. The thesis concludes with a review of potential policy measures that could help to reduce the future CO₂ emissions from road freight transport.

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Many friends have supported me during lifetime of the study. I greatly value their friendship and deeply appreciate their patience and faith in me. Special mention should go to Keith for allowing me the time to finish this work. He has been a constant source of encouragement and inspiration.

I would like to dedicate this thesis to my parents, Barbara and Zbigniew, and my sister Alicja. None of this would have been possible without their love and patience. They have always supported, encouraged and believed in me.

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Chapter 1. Introduction

Aims of the chapter:

- *To present the context and reasoning for the research*
- *To list and justify the research questions addressed by this thesis*
- *To outline the structure of the thesis*

Although vital to satisfying the needs of today's society, road freight transport also poses a large environmental burden. The dominant environmental issue of our age is climate change. Road freight accounts for 5-6% of the UK's carbon footprint. Government and companies are intensifying their efforts to reduce carbon dioxide (CO₂) emissions from road freight transport. Ambitious targets to reduce CO₂ and other greenhouse gases (GHGs) by 2050 have now been set. What are the prospects of road freight sector achieving them? Will new policy interventions be required? These are the topical issues that this research addresses.

This chapter introduces background information on the research project and is divided into five sections. Firstly, the extent of road freight transport and its environmental impact are outlined to put the research into context. The research was carried out as part of major research project called Green Logistics. The second section briefly describes this project. In the next section, the research questions that will be addressed in the thesis are presented. The Chapter concludes with an overview of all the chapters to familiarise the reader with the structure of the thesis and underlying logic of the research. Finally, the scope of the research is outlined.

1.1. Research Background

Every year, vast amounts of raw materials, components and finished products flow through complex supply chain systems to reach the ultimate customers. A supply chain can be described as “a network of connected and interdependent organisations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users” (quoted in Christopher, 2005, p.6). Freight transport plays a critical role in ensuring a smooth, cost- and time-effective fulfilment of customers' requirements. There were 1734 million tonnes transported by road in the GB-registered lorries in the UK in 2008 (Department for Transport, 2009a), equivalent to 55.3 tonnes per person. Road freight transport

accounted for 82% of the total tonnes lifted in that year. All this road freight movement imposed a heavy burden on the environment.

Environmental issues associated with road freight transport have been receiving increasing attention over the last few decades. There is a vast body of literature available on its external impacts such as air pollution, noise and vibrations, impact on land use and biodiversity, waste, congestion, accidents and even visual intrusion. Most of the externalities associated with road freight transport have already been subject to legal environmental controls. Carbon dioxide (CO₂) emissions are the only externality that still remains unregulated.

As a result of burning fossil fuels, CO₂ concentrations in the atmosphere have increased by over one third since pre-industrial times (around 1750) and now stand at 387 part per million (ppm) (Stern, 2006, NOAA, 2010). In recognition of the potentially catastrophic consequences of rising CO₂ and other GHG levels, governments are taking action at global, national and local levels to address the problem. According to the Stern report, transport is responsible for 14% of the global greenhouse gas emissions with three-quarters of these emissions attributable to road transport (Stern, 2006). As concern for the negative consequences of global warming and the general environmental awareness of the customers rises, companies must take more account of the external impacts of their logistics activity, not only by complying with existing legislation but also by acting proactively in anticipation of future government measures.

Recently, the UK government has committed to reduce emissions of GHGs to at least 80% below 1990 levels by 2050. In the light of this legally binding GHG reduction target, there is a need for new policies and measures focusing on the transport sector. Road freight transport is one of the industry segments where further improvements are needed. However, to be able to assess the full consequences of new policies, it is crucial to have a baseline against which the anticipated policy benefits could be benchmarked. Hence, there is a need for a reliable forecast of future CO₂ emissions from road freight transport in the absence of new policy interventions. Most currently available transport forecasts focus on passenger traffic. Where available, forecasts of road freight volumes and related externalities are typically linked to trends in economic activity, ignoring changes in the nature of logistics and supply chain systems over the medium to long term.

In order to address this gap, this research seeks to explore and map the complex relationships between economic growth and road freight transport trends, as well as to provide a comprehensive framework linking these parameters to road freight-related CO₂ emissions. This framework will be then used to investigate the intensity and direction of future trends in the key logistics and road freight transport variables and to identify the main factors determining these trends up to 2020. To obtain a realistic view of future changes in the transport and distribution sector, this the research has involved extensive consultation with logistics and supply chain practitioners. Based on their projections of changes in the road freight transport levels and key logistics variables, a business-as-usual (BAU) forecast of CO₂ emissions from Heavy Goods Vehicles (HGVs) in 2020 will be constructed. The business-as-usual (BAU) forecast assumes that future changes will only be influenced by policies and measures adopted in the past, i.e. no new policy options or initiatives are assumed for the BAU scenario. This forecast will then be assessed in the light of the UK GHG reduction target. This will be supplemented by a review of potential policy measures that could help to reduce the future CO₂ emissions from road freight transport.

1.2. Green Logistics Research Project

The research presented in this thesis was carried out over a four year period during which the author was also involved in a major project at Heriot-Watt University's Logistics Research Centre. This research project, funded by the Engineering and Physical Sciences Research Council (EPSRC), was called Green Logistics and involved six UK-based universities and a number of private and public sector companies.

The primary aim of the project was to investigate ways in which the sustainability of logistics systems can be improved. The primary focus was on transport but associated activities such as inventory management, production scheduling, warehousing, materials handling and retailing were also considered. The challenge was to identify opportunities for improving the environmental performance of logistics and distribution in a cost-effective manner.

The part of the project the author had a responsibility for was entitled 'Understanding and Forecasting of Business-as-Usual Trends'. Its main objective was to examine the future course of key logistics and supply chain trends, as well as to analyse their underlying causes. Through participating in the Green Logistics project it was possible

to collect large amounts of data, some of which was used to prepare this thesis. Although the project involved efforts of researchers from six universities, the work presented in this thesis is author's own and all contributions from other consortium members are acknowledged in the text.

1.3. Research Questions

As mentioned above, **the primary aim of this thesis is to produce a forecast of the environmental impact of road freight transport in the UK up to 2020 on a business-as-usual basis.** In line with this main research objective, five further research questions are developed and examined in this thesis:

***RQ1:** What are the main factors determining the environmental impact of road freight transport and how they are related?*

***RQ2:** What methodologies can be used to establish a BAU forecast of CO₂ emissions from road freight transport and what are their main advantages and disadvantages?*

***RQ3:** From the logistics industry perspective, how are the main factors determining the environmental impact of road freight transport likely to change by 2020 on a BAU basis?*

***RQ4:** Up to 2020 what will be the main drivers of the changes in these key factors?*

***RQ5:** What additional policy measures can be applied to reduce the CO₂ emissions from road freight transport?*

In order to answer these questions, the research process has been divided into the following stages:

1. A comprehensive literature review was conducted to establish the main factors influencing the environmental impact of road freight transport and their inter-relationships.
2. Different methodologies used in the past to forecast the environmental impacts of road freight transport were reviewed to identify the most suitable approach given the aims and objectives of this thesis.

3. Primary data was collected from a large sample of logistics specialists in focus group discussions and a two round Delphi survey. This was analysed using a range of statistical techniques.
4. On the basis of the earlier theoretical and empirical work, a spreadsheet model was constructed, linking volumes moved, demand for road freight transport and the CO₂ emissions from truck traffic.
5. This model was used to forecast the future environmental impact of road freight transport on a BAU basis and key factors were varied to see how the BAU case might be modified to reduce the carbon footprint of the road freight sector.

1.4. Thesis Structure

The remainder of the thesis consists of seven chapters and is divided into three parts (Figure 1.1). In the theoretical part (Chapters 2 and 3), the available literature and previous research on the subject is reviewed to provide academic background to this research. The methodology used in this research is outlined in Chapter 4. This chapter links the theoretical and empirical parts of the thesis and describes the procedures used to collect and analyse data necessary for the research. Chapters 5 to 7 present the research undertaken and discuss the empirical findings. Chapter 8 concludes the thesis, discusses its contribution to knowledge, outlines its limitations and indicates directions for future research.

Chapter 2 introduces the concept of supply chain management, logistics and freight transport. It also discusses the idea of sustainable development and its application to logistics. This leads to the concept of green logistics, its development and main assumptions. In the second part of this Chapter, the external impacts of road freight transport are reviewed and the magnitude of the related environmental problems highlighted.

Chapter 3 reviews the literature on the main factors influencing the CO₂ emissions from road freight transport. It examines statistical trends in the key logistics variables and introduces the conceptual framework which underpins the research. The main driving forces behind the changes in the key variables are also explored.

The philosophical assumptions underpinning this research and the research design are discussed in Chapter 4. The chapter commences with a justification of the critical realist paradigm which has been adopted as the philosophical stance of this thesis based on the study's ontological and epistemological foundations. It then presents and justifies the research methods applied throughout the project.

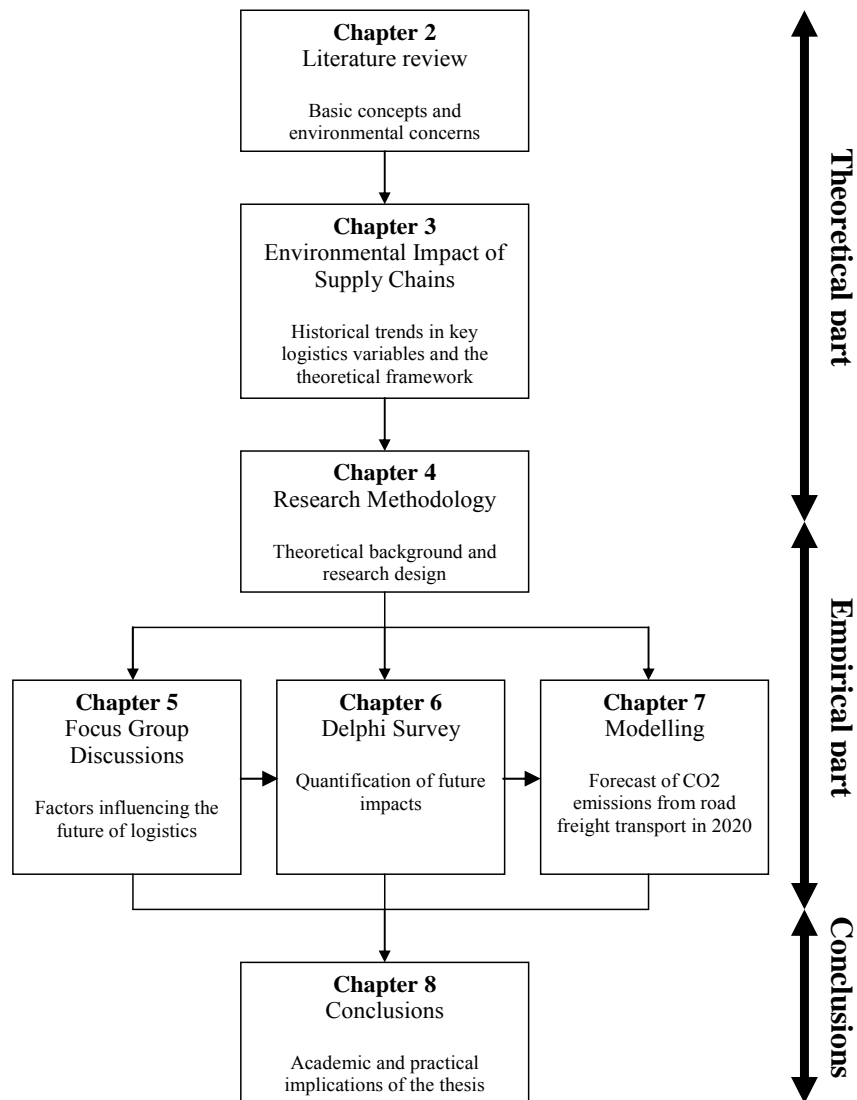


Figure 1.1. Thesis structure

Chapter 5 presents the findings of the focus group discussions and considers their implications for the road freight transport sector. It adopts a combined confirmatory-exploratory approach to test the accuracy of factors identified in the theoretical part of the research and to seek in-depth understanding of the complex reality of logistics and supply chain management. The findings are then used to develop a questionnaire survey applied at the next stage of the research process.

The results of the Delphi survey are discussed in Chapter 6. This survey aimed to quantify the scale of future changes in the key logistics variables and forces behind them. Based on the average responses, a BAU scenario of future developments in the road freight transport sector is constructed.

Chapter 7 presents the results of the modelling work. A spreadsheet model was developed to estimate future CO₂ emissions from road freight transport. The average projections elicited from the Delphi survey results were input into the model to derive a BAU forecast of CO₂ emissions from HGVs in 2020. A number of alternative scenarios are also modelled to illustrate the range of possible future trajectories in road freight-related CO₂ emissions. Finally, potential policy options for reducing the environmental impact of the sector are reviewed.

Chapter 8 concludes the thesis summarising the main findings of the research. It also lists theoretical and practical contributions of this research and its potential limitations. The directions for future research are also highlighted.

1.5. The Scope of the Research

This research is concerned with the environmental impacts of road freight transport in the UK. It focuses on the Heavy Goods Vehicles (HGVs), i.e. vehicles over 3.5 tonnes gross vehicle weight (gvw). Therefore, transport of goods by HGVs is meant every time reference is made to road freight transport throughout this thesis. The environmental impact of road freight transport is assessed with respect to its contribution to climate change, i.e. in terms of CO₂ emissions. Other externalities such as air pollution, noise, accidents, etc., are also specified but their detailed quantification is outside the scope of this thesis. The limitations of this research will be discussed in the concluding chapter.

1.6. Summary

It is expected that this thesis will contribute to a better understanding of the complex relationship between economic growth, freight transport activity and freight-related externalities. A BAU forecast of the CO₂ emissions from road freight transport up to 2020 will be produced. The general framework developed in the course of this research can be adapted to the specific requirements of government agencies in their development of a sustainable logistics strategy. This may involve greater use of alternative modes, more localised sourcing, improved vehicle utilisation and even some

relaxation of current just-in-time scheduling. The framework can also be applied at the micro-scale to the road freight operations of individual companies. This should ensure that this project brings both theoretical and practical value to the logistics and supply chain management discipline.

Chapter 2. Supply Chain Management, Logistics and Sustainability of Road Freight Transport

Aims of the chapter:

- *To define basic concepts*
- *To identify relationships and differences between concepts addressed by this thesis*
- *To highlight the importance of environmental concerns associated with road freight transport*

This chapter is the first of two chapters reviewing literature related to the research problems examined in this thesis. Firstly, the basic concepts are defined. Then, different stages in the evolution of logistics knowledge are outlined and the current state of the discipline is presented. In the second part of this chapter, the sustainability concept is introduced and the magnitude of the environmental impact of road freight transport is assessed. Also, different approaches to measuring CO₂ emissions from road freight transport are discussed. Overall, this chapter provides a justification for the subject and importance of this research.

2.1. Definitions

In this section, the terms supply chain management, logistics, transport and green logistics are defined in order to ensure their clarity and consistent meaning throughout the thesis.

2.1.1. Supply chain management

There are many ways of defining supply chain management in the literature. In order to define supply chain management, first a concept of supply chain will be introduced. Christopher (2005) quotes the following definition of supply chain: “a network of connected and interdependent organisations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users” (p.6). A broad range of supply chain management definitions is discussed for example by Lummus et al. (2001) or Mentzer et al. (2001). In concluding their review, Mentzer et al. (2001) state that supply chain management is “the systematic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses

within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole” (p.18).

With time, the original concept of supply chain management has evolved. Christopher (2005) suggests that “while the phrase ‘supply chain management’ is now widely used, it could be argued that it should really be termed ‘demand chain management’ to reflect the fact that the chain should be driven by the market, not by suppliers” (p.5). Thus, supply chain management is changing its focus from supply cost-led issues to demand driven value (Christopher et al., 2005, Jacobs, 2006, Walters, 2006, Juttner et al., 2007, Zokaei and Hines, 2007). The concept of value chain was first popularised by Porter (1985). He emphasised that “the value chain disaggregates a firm into its strategically relevant activities in order to understand the behaviour of costs and the existing and potential sources of differentiation. A firm gains competitive advantage by performing these strategically important activities more cheaply or better than its competitors” (Porter, 1985, pp. 33-34). Value activities can be divided into two broad groups, primary activities and support activities (Figure 2.1). Primary activities are the activities leading to physical creation of a product, its distribution, sale, and after-sales service. Support activities support primary activities and each other by providing inputs, technology, human resources and infrastructure. Competitive advantage is a function of how a company integrates and manages these value activities.

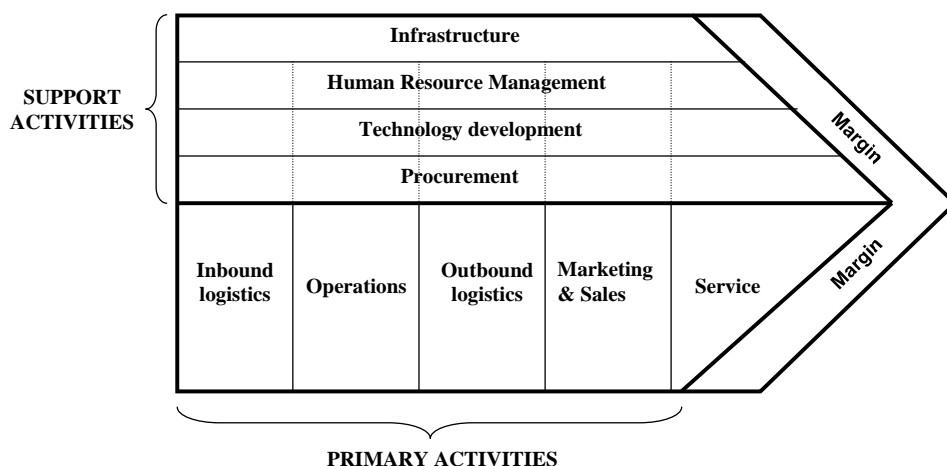


Figure 2.1. The value chain
Source: Porter, 1985

Further, a company’s value chain is embedded in a larger system, where different links in the network (for instance suppliers or customers) have their own value chains. Childerhouse and Towill (2003), conclude that a supply chain comprises in fact one or

more value chains. This subsequently leads to the concept of value chain management (Walters and Rainbird, 2004), which incorporates the principles of Value Based Management (VBM) and supply chain management with a main focus put on creation of real value not short-term profits (Christopher and Ryals, 1999, McGuffog and Wadsley, 1999). Although the presented concepts differ in emphasis, they are all encompassed in the broad definition of supply chain management presented above.

2.1.2. Logistics

The US Council of Supply Chain Management Professionals defines logistics as “that part of the supply chain management that plans, implements and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers’ requirements” (CSCMP, 2008).

Christopher (2005) describes logistics as “the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organisation and its marketing channels in such a way that current and future profitability are maximised through the cost-effective fulfilment of orders” (p.4). As with the supply chain management concept, he emphasises the value-creating aspects of logistical activities. This definition mirrors the main objective of every business of creating additional value for its stakeholders. Traditionally logistics was only concerned with the outbound movement of products to customers. Over the past 15 years interest has grown in the transport of goods from final consumers back along the supply chain for reuse, recycling or ultimate disposal, the subject now known as reverse logistics (Rogers and Tibben - Lembke, 1998, Beamon, 1999).

Typically, logistics encompasses the following elements (Coyle et al., 1988, Lambert et al., 1998, Rushton et al., 2006):

- Storage, warehousing and materials handling
- Transport
- Purchasing
- Inventory
- Information and control
- Packaging and unitisation.

Although both logistics and supply chain management concepts are already relatively well established within both academia and practice, a survey conducted by Larson et al. (2007), revealed lack of consensus on the relationship between logistics and supply chain management amongst supply chain executives. According to Lambert (2001), initially supply chain management was viewed as not ‘appreciably different’ from the concept of logistics and was basically understood as “logistics outside the firm to include customers and suppliers” (p.100). Larson and Halldorsson (2004) list four perspectives on the relationship between logistics and supply chain management (Figure 2.2) and confirm their practical existence based on a sample of 98 logistics experts. In the traditionalist perspective, SCM is positioned within logistics and perceived as “a special type of logistics, external or inter-organisational logistics” (p.19). This is consistent with the initial perception of supply chain management observed by Lambert (2001). The re-labelling approach simply changes the nomenclature. The term logistics is substituted by supply chain management, without any changes in its scope and meaning. In the unionist perspective, supply chain management subsumes logistics. Unionists view supply chain management as consisting of logistics, strategic planning, operations management, information technology, marketing and sales. Intersectionists argue that supply chain management should be viewed as a broad strategy that cuts across different functions and processes both within the organization and through the channels. In this perspective, “supply chain management is not the union of logistics, marketing, operations management, purchasing and other functional areas. Rather, it includes strategic, integrative elements from all these disciplines” (p.21).

Lummus et al. (2001) and Cooper et al. (1997), also discuss the connection between logistics and supply chain management. The former authors state that supply chain management goes beyond the logistics function and should be considered a strategic management tool used to make business processes more efficient in order to enhance overall customer satisfaction and, hence, create additional value for the company. Their perception is consistent with the intersectionist approach. Cooper et al. (1997) conclude that “supply chain management is the integration of business processes from end user through original suppliers that provides products, services and information that add value for customers” (p.2). Thus, supply chain management should not be used as just another name for logistics as it includes a wider scope of activities, for example information systems integration or coordination of planning and control activities. This can be regarded as the unionist approach.

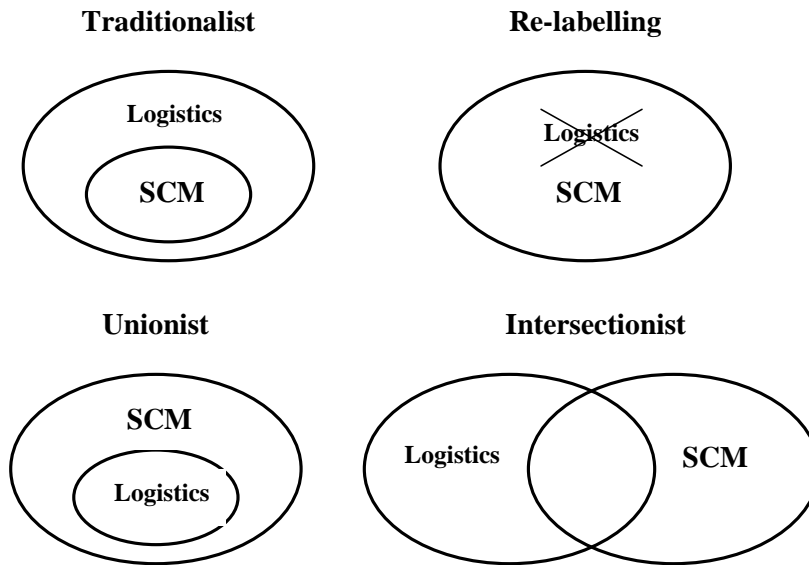


Figure 2.2. Four perspectives on logistics versus supply chain management
Source: Larson and Halldorsson, 2004

2.1.3. Freight transport

Amongst other elements, logistics involves the physical movement of goods between different points along the supply chain. “Freight transport is the method by which goods move from one location to another and it is an essential function in product supply chains as it provides the physical movement between the suppliers and customers” (Emmet, 2005, p.1). This definition is extended by Lambert et al. (1998). They define freight transport as an operation providing for the movement of materials and goods from point of origin to point of consumption, and perhaps to its ultimate point of disposal and point out that transport is a key logistics activity. As transporting goods for disposal recycling is becoming more and more important and reverse transport and logistics receive increased attention (for example Rogers and Tibben – Lembke (1998) or Dethloff (2001)), this wider definition is adopted in this thesis.

Transport cost may represent a substantial part of the price of goods, especially in the case of low value, bulk commodities (Emmet, 2005). On the other hand, in case of high value-density products, transport usually represents only a small percentage of the total cost. In 2003, transport costs represented on average only 2.6% of sales revenue (ELA and A.T. Kearney Management Consultants, 2004). This can result in the priority being given to customer service requirements rather than to optimisation of the transport operation. Although the situation is continuously improving, transport still tends to be

given a relatively low status within organisational hierarchies dominated by production, marketing and sales. Consequently, it often needs to be optimised within the boundaries and constraints set by other departments which regularly impairs its efficiency (McKinnon, 2006a).

The transport of goods within supply chains is performed using one of five possible transport modes: road, rail, water (including deep sea, coastal and inland waterways), pipelines or air (Gubbins, 1996, Emmet, 2005). Road is the dominant freight transport mode in the UK as it currently carries around 65% of the total tonne-kilometres moved and 82% of tonnes lifted (Department for Transport, 2009a,b). Further, road freight transport is crucial for the national economy. It was estimated that for the UK economy as a whole the loss of road transport for just one week would have devastating consequences (McKinnon, 2006b). Thus, this thesis focuses on road freight transport and other modes are only considered in the context of their potential to alter road's share of the freight market.

2.2. The Evolution, Current State and Future of Logistics

Early references to logistics are found primarily in the military texts (Lummus et al., 2001). Physical distribution as an area of business study first appeared in the academic literature in the early 1900s, in the context of the transport of farm products and its contribution to fulfilling strategic objectives of an organisation (Kent and Flint, 1997, Lambert et al., 1998). This was what Kent and Flint (1997) call an "farm to market" era (Era 1) in their six stage classification of the logistics thought evolution. It was followed by the period when distribution was considered a subset of marketing and viewed as a set of segmented functions (Era 2). In Era 3, the functional areas became integrated and a system approach was sought to be contributing to the development of "integrated logistics". In the next era, the customer focus emerged as a primary concern of a business organisation. Physical distribution became a component of customer service. In Era 5, logistics started to be viewed as a critical component in a company's strategy and a key differentiator of an organisation. This continues through to the present. As Era 6 concerns the future, the authors speculate that the focus will be on behavioural issues and customer perceptions of a firm's logistics system. A stronger focus on interfunctional cooperation and coordination should also emerge, leading towards more integrated supply chain management.

Rushton et al. (2006) and Ballou (1985) describe the development of logistics throughout decades of the 20th century in a similar manner. In the 1950s distribution systems were fragmented and poorly planned and logistics did not exist as a field of managerial practice. The next two decades saw the development of physical distribution concept and recognition of the interrelated nature of logistics functions. In 1962, Peter Drucker, in his article in Fortune magazine, declared physical distribution as one of “the most sadly neglected, most promising areas of American business” and emphasized the challenges of the field: “We know little more today about distribution than Napoleon’s contemporaries knew about the interior of Africa. We know it is there, and we know it is big, and that is about all” (quoted in Coyle et al, 1988, p. 10). In the 1970s many companies recognized the need to include distribution in the functional management structure of an organization and began to embrace the logistics concept. There was also a major change in the structure and control of the distribution chain with a marked increase in the power of major retailers in some countries. The 1980s can be described as an era of a significant increase in professionalism within distribution. The growth of the third-party distribution was also notable, reflecting outsourcing of logistics function. Advances in information technology in the late 1980s and early 1990s resulted in even greater integration of the inbound and outbound distribution-related functions. The term “logistics” was used to describe this concept. In the 1990s this process evolved further, encompassing also functions outside organizational boundaries and the idea of supply chain management was advanced. According to the authors, in the 21st century, logistics is considered to be a key enabler for business improvement and an important source of competitive advantage. Many organizations actively contribute to further advances in the field as they have realised that logistics is a ‘value-adding’ activity and can contribute to major enhancements of their competitiveness.

According to Ballou (2007), the concept of supply chain management is now mature and organizations are concerned with realizing the opportunities from integrated management of product flow processes across functions and between channel members. However, coordination, integration, relationship building and collaboration can be somewhat limited to the company and first-tier suppliers. Further, as it was noted above, logistics is being perceived as a subset of supply chain management. He also warns that by integrating so many functional areas across the firm and its network, supply chain management is in danger of becoming too broad and, thus, losing its identity and focus.

In other academic literature, there is a great deal of discussion whether or not supply chain management can be regarded as an academic discipline (Cousins et al., 2006). Harland et al. (2006) based on criteria of coherence, quality, impact and presence of a disciplinary debate conclude that supply chain management cannot yet be called a discipline in its own right. However, there appears evidence that it is an emerging discipline as “there is coherence in the supply management discipline-debate, the quality of supply management discipline research is improving and there is a discipline-debate occurring” (p.747). Similarly, Storey et al. (2006) agree that supply chain management is at an emergent stage. Vachon and Klassen (2006) conclude “as the field of supply chain management evolves to become a discipline of its own right, it must explicitly recognise linkages to related disciplines, and capture concepts and theories that form a broader strategic view” (p.796). In this thesis, supply chain management is considered as a developing discipline and this is what is meant every time reference is made to supply chain management as a discipline throughout this work.

Apart from discussion about its disciplinary status, Lancioni (2000) provides some insight into the opportunities and challenges facing supply chain management in the future. His list includes viewing supply chain management as a multi-dimensional discipline, continual customer focus, optimal supply chain design, ensuring agility of the chain and measuring performance in order to support effective management of the supply chain. Storey et al. (2006) suggests that the future of supply chain management will be mostly affected by trends towards globalization, outsourcing, fragmentation and market polarization.

Christopher (2008) lists five main trends that are likely to shape supply chain management in the future. These are:

- The changing balance of power due to increasing consolidation of both the supplier and the customer base.
- Further fragmentation of consumer markets and the demand for customized solutions.
- Customers expect high levels of responsiveness and lower prices at the same time.
- Demographic changes will impact demand pattern and product flows.
- The impact of ‘peak oil’ on transport costs will, in turn, affect sourcing and manufacturing location decisions.

No explicit reference to the environment is made in these earlier papers, despite major government and corporate concern about climate change. Environmental considerations and their role in logistics and supply chain management are identified as one of the key future factors by Enarsson (2008) and Skjoett - Larsen (2000). A recent survey by McKinsey & Company confirms this view. The survey result show that 60% of global executives already view climate change as important to consider within their companies' overall strategy and 49% say it is important to account for climate change in the areas of purchasing and supply chain management (McKinsey & Company, 2008). This links to the second part of this chapter, where the environmental impacts of logistical activities are reviewed.

2.3. The Concept of Sustainability

The concept of sustainable development was explained and popularised in the Brundtland report (World Commission on Environment and Development, 1987). The report stated that “humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs” (p.24). This definition emphasises the need to ensure systematic, responsible, long-term use of natural resources, so that the current consumption level does not compromise their availability for future generations. From another perspective the concept of sustainability can be looked at as “the modality of development that enables countries to progress, economically and socially, without destroying their environmental resources” (Leal Filho, 2000, p.10). At a company level, the concept of sustainable development is sometimes referred to as the ‘triple bottom line’ in the corporate decision making process. The triple bottom line means expanding the traditional performance measurement criteria to include ecological and social performance in addition to financial results (Elkington, 1998, Savitz and Weber, 2006). The concept of the triple bottom line in case of road freight operation is shown in Figure 2.3.

Sustainability requires organizations to take a holistic and integrated approach to managing their economic performance, human resources and environmental impacts. As Wilkinson et al. (2001) suggest “both human and ecological sustainability can shift the focus from short-term corporate survival to longer-term business success and ecological survival, with both requiring a shift in criteria from short-term financial profits to long-term returns” (p.1494). As with the increase of income, people become

more environmentally and socially / ethically aware, sustainable strategy is becoming an effective approach to seeking enduring competitive advantage and securing stakeholder approval (Markley and Davis, 2007). Hence, sustainability can become a key element in ensuring the long-term profitability and success of a business.

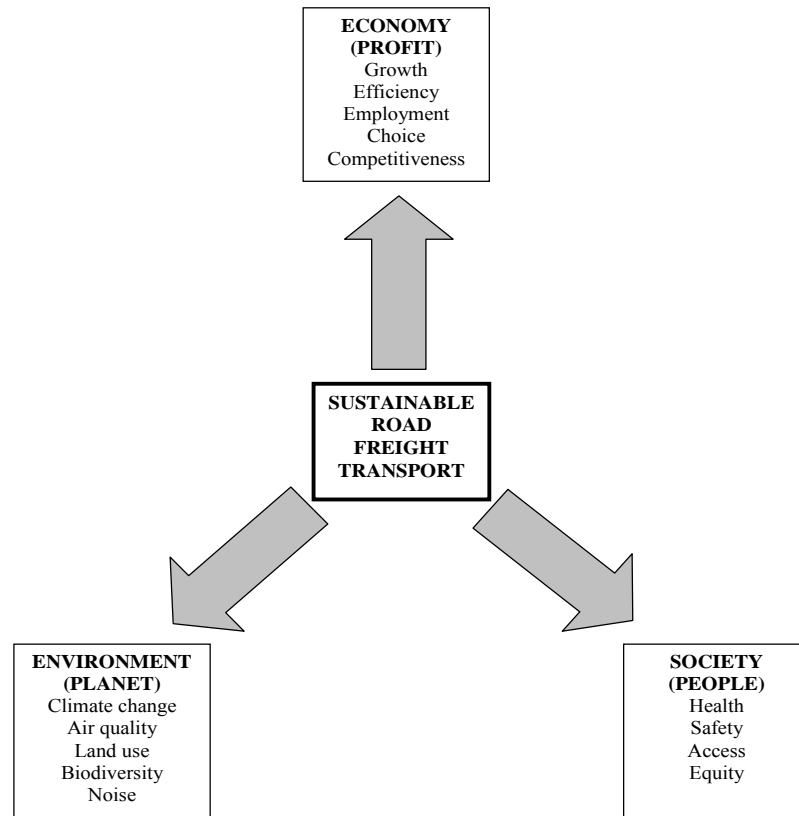


Figure 2.3. Sustainable road freight transport- the triple bottom line
Adapted from: www.greenlogistics.org

Further, there is a tendency to identify sustainable development with environmental performance (for example Hill, 2001). However, it is important to emphasise that the social element should not be ignored. “For true corporate sustainability, an organization must recognise, value and promote the capability of its people. For human resource sustainability to be achieved, therefore, the human resource policies and practices need to be integrated for sustained business performance and positive employee outcomes of equity, development and well-being” (Wilkinson et al., 2001, p.1497). Wider social responsibility aspects are also increasing in importance, for instance co-operation in the developing world, labour practices, diversity and human rights, safety or philanthropy (Carter and Jennings, 2002, Markley and Davis, 2007). In the logistics area, Carter and Jennings (2002) identified six areas comprising what they call ‘socially responsible transportation’. These include: environmental considerations, ethics, diversity, quality

of life for drivers, safety and philanthropy / community. Similarly, Murphy and Poist (2002) conclude that “if the logistics discipline is to reach its full growth and potential, it must become more accepting of the concept that logistics managers have a responsibility to seek socially beneficial results along with economically beneficial ones in their decision making” (p.35).

Whitelegg (1994) differentiates between two broad interpretations of sustainable development:

- **Weak sustainable development** – where environmental considerations are taken into account in decision making but can be traded-off against other economic and social objectives.
- **Strong sustainable development** – where environmental considerations impose an absolute constraint on the achievement of other economic and social goals.

Whitelegg (1994) also argues that the position of weak sustainable development “effectively categorises environmental issues as important only when they do not conflict with other policy goals” (p.5). He clearly favours the strong sustainable development principle claiming that in practice overall economic and social objectives are more likely to be achieved through decisions informed by environmental principles. Within freight transport and logistics, “strong sustainability will be aimed at the growth process itself and through structural change, spatial readjustments, ecological taxation, strengthening of local economies and some modal transfer will reduce the level of demand for freight transport whilst protecting and enhancing social and economic objectives” (p.5).

In its Sustainable Distribution document (DETR, 1999) and subsequent policy statements (for example Department for Transport, 2008a) the British government has identified a series of policy measures designed to make logistical operations more sustainable in economic, social and environmental terms. Sustainable distribution is concerned with achieving specific outcomes, which are presented in Figure 2.4. The interdependence of these outcomes needs to be clearly recognised as the failure to address problems in one area will eventually inhibit progress and improvements in other areas (for example failure to address the problems of health, safety, noise or access would eventually threaten continued economic growth, which, in turn, would affect

prosperity, competitiveness and the ability to tackle pollution, climate change and other environmental problems).

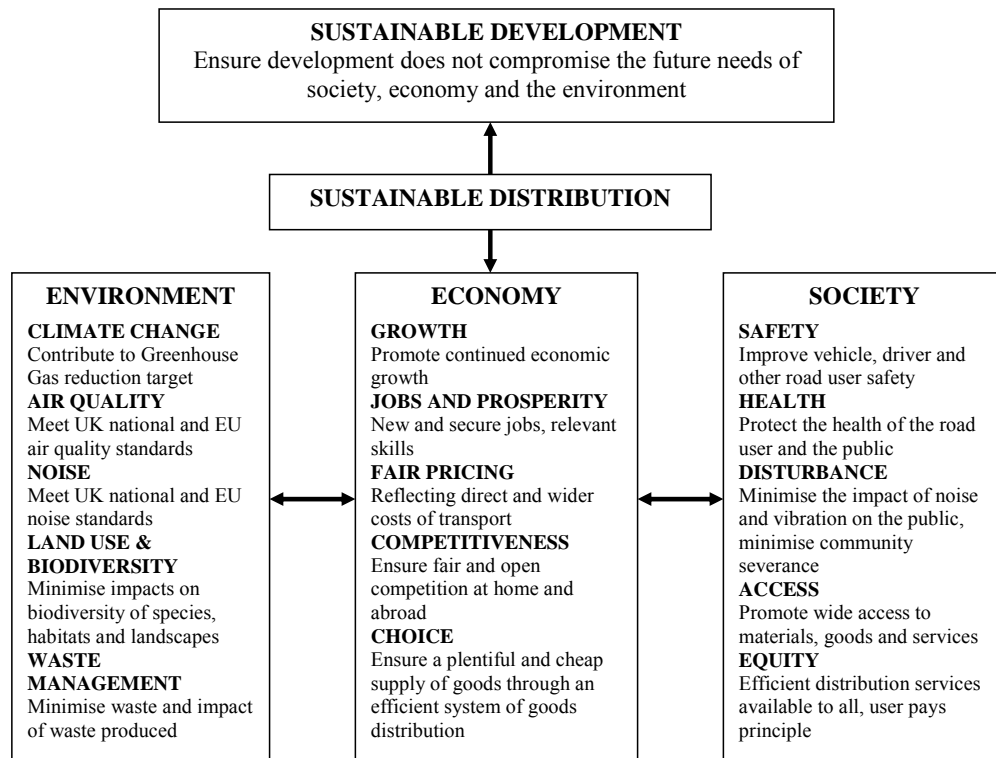


Figure 2.4. Sustainable distribution: a strategy
Source: DETR, 1999

Although the importance of all aspects of sustainable development and operation is recognised in this thesis, the environmental element of the concept is given particular attention. This research focuses on the contribution of logistics to climate change and in particular CO₂ emissions from freight transport activities.

2.4. Green Logistics

This section introduces the concept of green logistics, its development and implications for organisations.

2.4.1. Green logistics and supply chain management

Rogers and Tibben-Lembke (2001) define green logistics as “efforts to measure and minimise the environmental impact of logistics activities” (p.130). Initially, environmental considerations in supply chains resulted in the development of a new sub-sector of logistics, namely reverse logistics. In the 1990s, reverse logistics was perceived as a major new market for logistics services, based mostly upon increasing

societal concerns over hazardous and solid waste disposal and recycling (Rodrigue et al., 2001). Although in the literature the term green logistics is still often used as a substitute for reverse logistics (for example Byrne and Deeb, 1993), Rogers and Tibben-Lembke (2001) demonstrate the differences and the overlap between reverse and green practices (Figure 2.5). As they emphasise, there are many logistics-related activities to which both terms can be equally applied. However, the terms are not synonymous. Broadly defined, reverse logistics encompasses shipments of waste, recyclables and customer returns in the logistics systems as well as efforts to reduce these reverse flows (Wu and Dunn, 1995). As the greening of distribution starts right at the source of supply chain and works its way through its every stage to ultimate consumer or disposal point, it is not enough to limit environmental initiatives to reverse logistics, hence the need to differentiate between the two terms (Van Hoek, 1999).

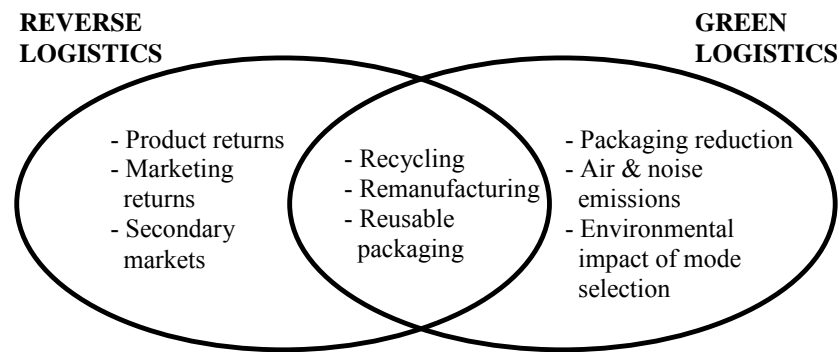


Figure 2.5. Relationship between reverse and green logistics
Source: Rogers and Tibben – Lembke, 2001

As the attempts to define green logistics in published literature are rather limited, drawing on the Council of Supply Chain Management Professionals' definition, green logistics can be defined as “that part of the supply chain management that plans, implements and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements at a minimum environmental cost”.

Goldsby and Stank (2000) emphasise the central role of logistics to environmental performance of a company. “Given that logisticians are involved in decision areas ranging from network design, purchasing, transportation management, inventory management, materials handling, packaging, return goods handling, and after-sales parts

and service management, it becomes apparent that logistics plays a prominent role in the implementation of virtually any environmental strategy” (p.187). Thus, green logistics is becoming increasingly important and road freight transport as a central logistics activity should receive particular attention.

As was discussed earlier, logistics is an integral part of supply chain management. Consequently, research on environmental considerations affecting logistics operation have moved beyond green logistics into the concept of green supply chains. According to Rao (2002), green supply chain management encompasses environmentally responsible practices involved in “purchasing, marketing, distribution, logistics and operations management, and the issues involved comprise customer-supplier relationship, delivery times, inventory management, product development and purchasing” (p.635). Although this thesis is concerned with CO₂ emissions from road freight transport in particular, reference will also be made to other aspects of logistics and supply chain management as they provide a context for assessing the environmental impacts of HGVs.

2.4.2. The development of green logistics

The development of green logistics is inherently rooted in the changing corporate attitude towards environmental problems. According to Walley and Whitehead (1994) the current business approach to environmental issues developed in two stages. In the first era, which lasted from roughly 1970 to 1985, companies faced with new environmental regulations did little more than comply with the regulations. During this period, companies were generally unwilling to internalise environmental impacts and this reluctance was reflected in the delegation of environmental responsibilities to local facilities. A failure to create environmental performance measurement systems was widespread, and managers tended not to view environmental concerns as realities that needed to be incorporated into business strategy.

However, during the mid to late 1980s, a shift in the regulatory framework, worsening of some environmental problems, and the maturing of the environmental awareness created an incentive for businesses to look beyond the narrow, predominantly technical approach. With regulations focused more on ultimate environmental results and less on the mechanics of compliance, managers began to exercise greater discretion in their environmental responses. As a consequence, companies began to formulate

environmental strategies and executives came to recognise that continued environmental action could be a source of additional value (Walley and Whitehead, 1994).

The shift in attitude was seen also in the road transport and logistics sectors. Although during the 1980s and early 1990s the focus in limiting emissions from road transport was still on technical solutions, the behavioural aspects gained increasing attention (Desey and Diobias, 1992). According to Murphy et al. (1996), during the 1990s leading trade publications indicated that “environmental issues will not only broaden the scope of logistics, but also transform the way logistics managers perform their jobs” (p.192). Environmentalism and the “green movement” were perceived as “emerging or future issues of major consequence for the logistics discipline” (Murphy, 1995, p. 6). In the 1990s, the trade press started to frequently publish logistics-related environmental articles. However, at this time, there were relatively few publications on this topic in the scientific literature (Murphy et al., 1996).

Since then the situation has begun to improve continuously. Abukhader and Jonson (2004) conducted a review of academic papers published between 1992 and 2001. They identified 34 papers concerned with reverse logistics, green supply chains and emission assessment in what they cluster as “logistics-related” journals and 28 further articles in “journals related to other disciplines”. A more recent literature review conducted by Aronsson and Huge Brodin (2006) has shown that between 1995 and 2004, 45 of the total of 2026 papers in major logistics and supply chain management journals addressed environment-related issues.

From an academic perspective, the subsequent reviews of doctoral research in supply chain management and logistics-related areas conducted by Stock (2001) and Stock and Broadus (2006) revealed that reverse and environmental logistics significantly increased in importance as a research topic between the periods 1992-1998 and 1999-2004, moving from 18th to 9th position in the ranking of most frequently investigated subjects.

To summarise, although the number of scientific publications is increasing, there is much scope for further research and investigation in this field. Aronsson and Huge Brodin (2006), emphasise that “the role that the logistics system can play in reducing the environmental impact of industries has not been extensively researched. It is

especially important to understand the relationship between operational effectiveness and environmental aspects” (p.395). Other researchers also point out that although there is a lot already being done, still “green supply chain research should move from anecdotal studies towards an empirical, theoretical grounded approach” (Ferretti et al., 2007, p.237).

2.4.3. The economy versus environment dilemma in logistics

At a company level, the important question is, is the traditional economic objective in conflict with environmental goals or is there a synergy between these two? In the literature, at one extreme so called ‘green-gold measures’ are described which yield both environmental and economic benefits and avoid the need for cost benefit trade-off. They include initiatives like, for instance, backloading, shared-user distribution or application of computerised routing and scheduling systems. At the other extreme are measures that carry a cost penalty. These represent the strong form of sustainability concept (McKinnon, 2003). ‘Green-gold’ measures have already been widely applied within logistics and supply chain management. However, if a company decides to undertake an environmental initiative not yielding direct economic benefits, it usually expects some rewards from ‘portraying’ itself as green business, particularly in the form of greater customer loyalty and increased sales.

According to Quariguasi Frota Neto et al. (2008), although the win-win situations are possible, only a limited number of initiatives for improving the environmental performance of supply chains have proved to be profitable. Substantial improvement in green performance is usually only possible with significant investments, hence organisations aiming to reduce the environmental burden they impose, should look for trade-offs between ecological impact and financial costs. On the other hand, Wu and Dunn (1995) argue that “being environmentally responsible means improving operational efficiency by conserving resources and reusing them as much as possible.....When a firm’s objectives are cost minimisation and profit maximisation, continuous improvement of the process to reduce end-of-pipe contamination and focusing on pollution prevention makes sense” (p.22). The green initiatives are also likely to bring unanticipated indirect benefits, often difficult to quantify in a traditional cost-benefit analysis, for example good environmental image of a company in the eyes of consumers (Wu and Dunn, 1995). As a result the expanded market share may bring more profit to the company to offset the higher costs associated with implementation of

environmental measures. Reduced liability is also one of the benefits of green logistics practices (Sarkis, 2001). Korpela et al. (2001) conclude that, in order to be able to obtain and sustain its competitive advantage in terms of logistics activities, a company needs to be perceived as environmentally friendly by its customers.

However, the important question is whether these benefits are achievable in practice. The study conducted by Gavaghan et al. (1998) has shown that primary motivators of green supply chain practices are internal corporate values, pressures from customers and economic benefits from reduced costs and production times, greater innovation, improved product quality and performance, reduced research and development costs and increased market share. Goldsby and Stank (2000), proved that there was a strong positive relationship between overall logistics competence and the implementation of green practices in logistics operation. Rao and Holt (2005) based on a survey of 52 representatives of companies with an environmental system in place, conclude that green supply chain practices (for example choice of suppliers by environmental criteria, design considerations, optimisation of processes to reduce waste, water use, emissions or noise, recycling, etc.) lead to increased competitiveness and economic performance. In another survey of 271 transport and logistics professionals, conducted by Eye For Transport (2007), 66% of respondents reported that the green initiatives they had implemented were not affecting the efficiency of their supply chains. 27% of participants reported seeing their current green transport and logistics initiatives improving the efficiency of their supply chains and only 8% reported worsening of efficiency due to greening. These studies suggest that, at a company or supply chain level, 'green-gold' measures still seem to be dominant, thus there is a strong link between environmental performance and economic benefit or at least the cost-neutrality of measures implemented.

At a macro-scale, the effectiveness of different measures in reducing GHG emissions can be assessed by using the concept of abatement costs. Abatement costs are "additional costs (or savings resulting) from the use of a technology with low greenhouse gas intensity compared with the intensity of the current technology projection (excluding secondary effects from a socioeconomic perspective)" (McKinsey & Company, 2007, p.9). One way of presenting the potential for abating GHG emissions is to construct a so called abatement cost curve. An abatement cost curve is a graph showing measures with a potential to reduce GHG emissions ranked according to

their cost effectiveness. So far abatement curves have been constructed, amongst others, by consultants from McKinsey & Company for a number of countries (for example UK, Sweden, Germany, Switzerland, USA and Australia). Only in its German study separate abatement cost curves were constructed for a range of sectors, including the transport sector (Figure 2.6). To date, no logistics sector specific graph has been developed.

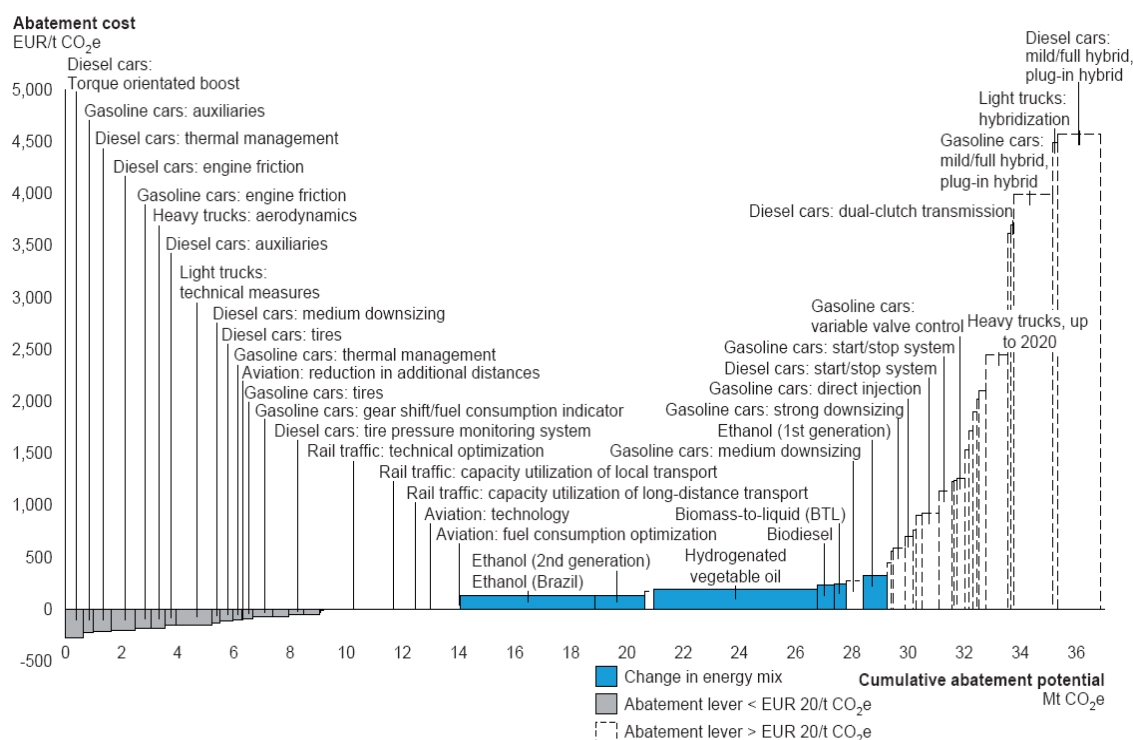


Figure 2.6. Abatement cost curve: transport sector in Germany
Source: McKinsey & Company, 2007

In the HGV sector, significant aerodynamic improvement brings both abatement potential and economic benefits. However, the additional 1.4 Mt CO₂e to be abated are very cost-intensive, i.e. the measurement bundle for HGVs up to 2020 costs over EUR 2000/t CO₂e. This shows that potential CO₂ savings tend to be more cost-effective at a micro-level, mostly because companies prioritise measures bringing them economic profits as well as environmental benefits. They also expect governments to bear the costs of new technology development and to provide businesses with ready-to-implement solutions. However, if savings in CO₂ emissions are made at a micro-level, eventually they will result in an overall cut in emissions from the road freight transport sector as a whole.

In the UK, Committee on Climate Change (2008) also uses the concept of abatement cost curves in their report. They focus on the supply-side abatement opportunities in

HGVs and assess potential for application of a number of technologies to reduce related CO₂ emissions in 2020. The Current Ambition scenario, presented in Figure 2.7, assumes some uptake of non-powertrain technologies and achieves emissions reduction of 0.3 MtCO₂ in 2020 in a fully cost efficient manner.

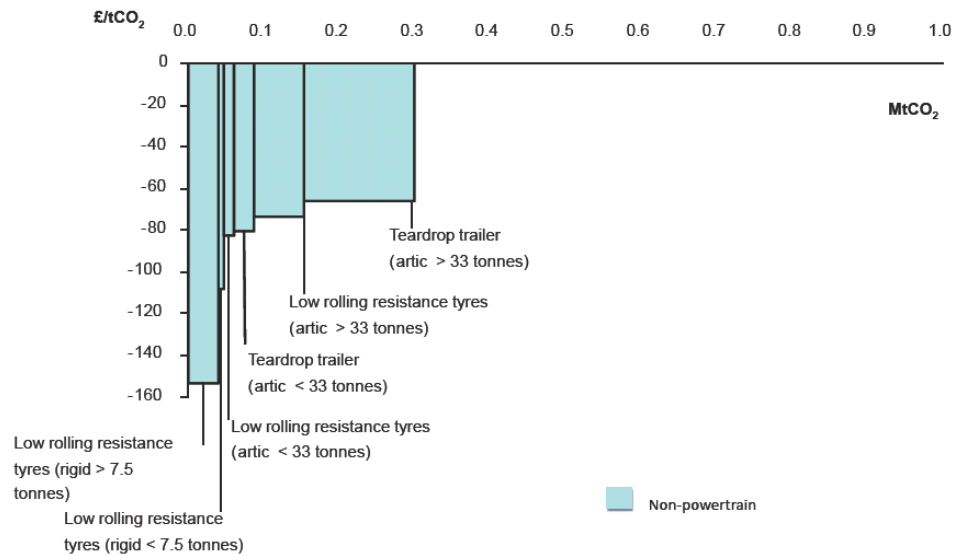


Figure 2.7. Marginal abatement cost curve for HGVs, 2020 (Current Ambition scenario)
Source: Committee on Climate Change, 2008

This thesis focuses on behavioural aspects of improving environmental performance rather than on technological advancements. This research aims to provide a framework to estimate the total CO₂ emissions from HGV activity in GB and likely future changes in these emissions within different scenarios. The aim is to operationalise the framework in a way that makes it possible to project the effects of potential changes in operating parameters such as average payload or average distance travelled.

2.5. Environmental Impact of Road Freight Transport

Transport is the single largest source of environmental impacts in the distribution system (Wu and Dunn, 1995). It is a main logistics activity for the majority of companies and the movement of freight by road causes the most serious environmental concerns (Cooper et al., 1994). In managing the transport operation, logistics managers have the ability to influence the following environmental issues: energy and raw materials conservation, land use, pollution (air, water, visual, odour and noise) as well as waste disposal (solid and hazardous) (Murphy et al., 1996, Beamon, 1999).

2.5.1. Emissions to air

Road transport contributes to air pollution at a local regional and global level (Figure 2.8). The concentration of most air pollutants diminishes significantly with increasing distance from the source. Hence, environmental damage is primarily local in nature. However, some pollutants cause more diffuse pollution at a regional scale. This occurs as primary pollutants are transported from their sources and transformed into secondary pollutants such as acid aerosols or ozone. Road transport emissions also cause global environmental problems, by contributing to climate change and ozone depletion (Johnstone and Karousakis, 1999). This section summarises the local, regional and global effects of exhaust emissions.

Effect	PM	HM	SO ₂	NO _x	NMVOC	CO	CH ₄	CO ₂	N ₂ O
Global									
Greenhouse - indirect									
Greenhouse –direct									
Regional									
Acidification									
Photochemical									
Local									
Health and quality of life									

PM – particulates, HM – heavy metals, SO₂ – sulphur dioxide, NO_x – oxides of nitrogen, NMVOC – non-methane volatile organic compounds, CO – carbon monoxide, CH₄ – methane, CO₂ – carbon dioxide, N₂O – nitrous oxide

Figure 2.8. Geographical extent of pollutant effects
Adapted from: Hickman et al., 1999

Local and regional air pollution

At a local level, air pollutants contribute to a range of health problems. The health effects can range from innocuous eye itching to chronic lung disease or heart failure. Hence, costs associated with health impacts of vehicle use are one of the largest environmental costs of road transport (McCubbin and Delucchi, 2003). Also, as a result of their toxicity, local air pollutants impose the largest negative impact in densely populated, urban areas (Doll and Wietschel, 2008).

At a regional level, oxides of nitrogen and sulphur dioxide contained in exhaust emissions contribute to acid rain. Acid rain has harmful effects on plants and aquatic animals. It can also cause damage to certain building materials (for example to sandstone, marble or granite), and is thus a particular threat to historical monuments (Likens and Bormann, 1974, Camuffo, 1992). Oxides of nitrogen also contribute to the creation of photochemical oxidants, mostly ozone (O₃), which is one of the major

constituents of photochemical smog (World Health Organisation, 2006). A summary of environmental and health effects of different air pollutants from road transport is given in Table 2.1.

Air pollutant	Effects
Carbon monoxide (CO)	Combined with haemoglobin in the blood forms carboxyhaemoglobin, reducing the blood's oxygen carrying capacity. Exposure to high concentrations results in loss of consciousness and death. At lower concentrations, CO affects the functioning of the central nervous system, causing impairment of vision and slowing reflexes and mental functions. Can also cause headaches and drowsiness.
Nitrogen oxides (NOx)	Involved in the formation of nitrous and nitric acid and contribute to eutrophication or acidification. Also involved in the formation of tropospheric ozone. Exposure is linked to increased susceptibility to respiratory infection, increased airway resistance in asthmatics and decreased pulmonary function.
Hydrocarbons (HC)	Hydrocarbons can cause irritation of skin and mucous membranes and may lead to breathing difficulties. Long-term exposure to hydrocarbons has been shown to lead to impairment of lung function. Hydrocarbons are also involved in the formation of tropospheric ozone and photochemical smog, which in turn may cause respiratory problems.
Particulate matter (PM)	Can irritate mucus membranes lining the respiratory tract and may give rise to breathing difficulties. Some constituents may be carcinogenic.
Sulphur dioxide (SO₂)	Associated with respiratory disease, chest discomfort and possible risk of mortality.
Lead (Pb)	Can be absorbed by gut or deposited in lungs. It is accumulated in the liver, kidney, brain, bone and nervous tissue and can cause gastro-intestinal colic, fatigue, headaches and other ailments related to circulatory, reproductive, nervous and kidney systems.

Table 2.1. Environmental and health effects of vehicle emissions
Source: Johnstone and Karousakis, 1999

Figure 2.9 depicts the relative contribution of different vehicle categories to the European emission totals for a range of air pollutants. HGVs are a major source of nitrogen oxides emissions from road transports. Lorries are responsible also for a large part of total particulate matter and hydrocarbon (methane) emissions. Thus, increased risk of cancer (particularly lung, liver, skin or respiratory cancer and leukemia), respiratory or cardiovascular symptoms are the main local effects associated with moving goods by road. Acidification and formation of photochemical smog are the two key HGV-related externalities at a regional level.

Local and national government policy-makers have prioritised the reduction of local and regional impacts of road freight transport. As a consequence, emissions from HGVs have been strictly controlled by EU legislation since the early 1990s (so called EURO emission standards). New HGVs have been the subject of progressively tightening emission limits for carbon monoxide, nitrogen oxides, hydrocarbons and particulate matter. According to Doll and Wietschel (2008), “vehicle emissions into the

atmosphere, other than CO₂, can be reduced more or less effectively by technical solutions. Alternative or synthetic fuels, filter technologies, engine-internal optimisation measures such as high pressure injection systems, exhaust gas recirculation or other solutions constitute possible options. Thus, non-CO₂ emissions will be - although they still constitute a top priority - of descending importance when discussing long-term sustainable transport systems” (p.4071). Figure 2.9 shows also that after cars, lorries are the second most important source of CO₂ emissions from road transport. CO₂ pollution has a direct global effect - it contributes to global warming and climate change.

Climate change

Climate change is one of the most serious challenges faced by mankind in the 21st century. The data from the Intergovernmental Panel on Climate Change (IPCC), demonstrates the continued relationships between fossil fuel combustion, carbon dioxide emissions and global warming. Global anthropogenic¹ GHG emissions have grown rapidly since pre-industrial times, with an increase of 70% between 1970 and 2004. Over the same period, annual CO₂ emissions have risen by 80% (IPCC, 2007). As levels of GHGs in the atmosphere continue to rise, the negative impacts on water balance, agriculture, natural ecosystems and human health are becoming more and more severe.

In December 1997, in response to the threat of global warming, the Kyoto protocol was adopted and it is now the most important international treaty regulating global GHG emissions. The Kyoto Protocol is an agreement made under the United Nations Framework Convention on Climate Change (UNFCCC) with an objective to stabilise GHG concentrations at a level that would mitigate anthropogenic climate change. Through ratification of the protocol, countries commit to reducing their emissions of six GHGs and to engaging in emissions trading if they maintain or increase emissions of these GHGs. The protocol covers emissions from six industry sectors: energy, industrial processes, solvents, agriculture, LULUCF (land use, land-use change and forestry) and waste (United Nations, 1998). While logistics or transport are not regarded in the Kyoto protocol as sectors in themselves, they cut across all sectors.

¹ Human-caused

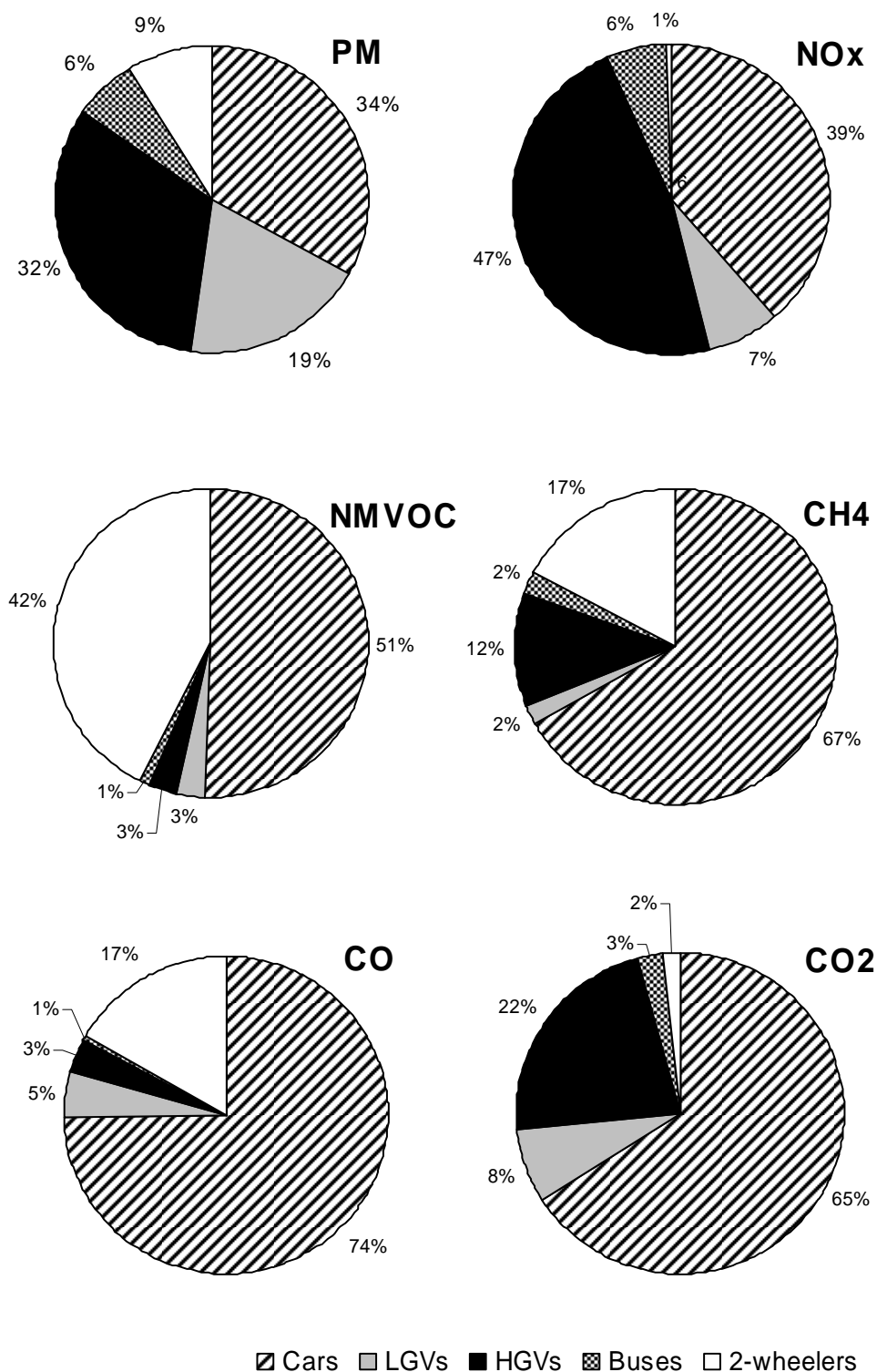


Figure 2.9. Emissions of different vehicle categories as a percentage of EU totals for road transport (based on 2005 data)

Data source: European Environment Agency, 2007

On a global scale, CO₂ accounts for the largest single contribution of any gas to the greenhouse effect, i.e. some 63% of the contribution of anthropogenic greenhouse gases (GHGs) to radiative forcing² in 2005 (Forster et al., 2007). In 2005, world energy-

² Radiative forcing is a measure of how the energy balance of the Earth-atmosphere system is influenced when factors that affect climate are altered, i.e. as the difference between the incoming radiation energy

related CO₂ emissions were estimated at 28.1 billion tonnes, while the world energy consumption was estimated at 462 quadrillion British thermal units³ (Btu) (Energy Information Administration (EIA), 2008). As a result of burning fossil fuels, since pre-industrial times (around 1750), carbon dioxide concentrations in the atmosphere have increased by over one third from 280 parts per million (ppm) (Stern, 2006). Data collected at Mauna Loa observatory in Hawaii indicate that CO₂ levels in the atmosphere now stand at 387 ppm and are rising at about 2 ppm each year as emissions continue unabated (Figure 2.10).

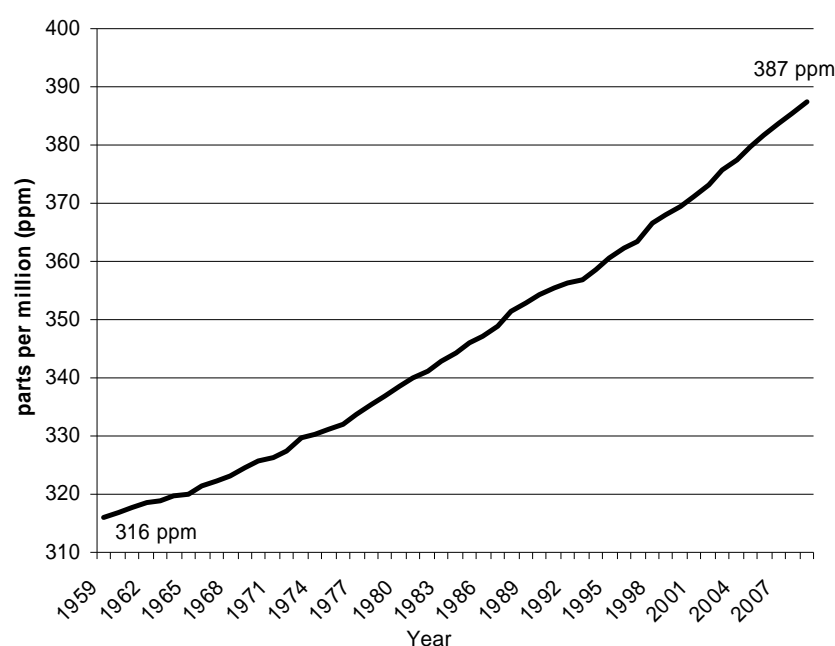


Figure 2.10. Average annual CO₂ concentrations (Mauna Loa, Hawaii)

Source: NOAA, ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_annmean_mlo.txt, (accessed on 28th February 2010)

The transport sector is responsible for a large share of world energy use (26% in 2004) and constitutes a major source of GHG emissions (23% of world energy-related GHG emissions in 2004) (Kahn Ribeiro et al., 2007). More than three-quarters of the total transport energy use and related CO₂ emissions are attributable to the road transport sector, while freight trucks accounted for 25% of the world transport energy use in 2000 (Fulton and Eads, 2004). The energy use by freight trucks is expected to increase by nearly 150% by 2050, as compared to 2000 level (WBCSD, 2004). Over the past decade, GHG emissions from transport have been increasing at a faster rate than from any other energy using sector. Moreover, globally, freight transport has been growing

and the outgoing radiation energy in the climate system. Radiative forcing is measured in Watts per square meter and when it is evaluated as positive, the energy of the Earth-atmosphere system will ultimately increase, leading to a warming of the system.

even more rapidly than passenger transport and this is expected to continue in the future (Kahn Ribeiro et al., 2007).

In 2006, the total domestic UK emissions of six GHGs reported under the Kyoto protocol were estimated at 652.30 MtCO₂e, while the CO₂ element was 554.52 Mt. (Choudrie et al., 2008). Nevertheless, a study conducted by Helm et al. (2007) suggest that when applying consumption-based measurement, the true extent of UK's emissions was almost twice as large at over 1100 MtCO₂e in 2003. In the UK, the transport sector accounts for around 24% of total domestic emissions of CO₂. Emissions from HGVs constituted 19.8% of the total transport-related CO₂ emissions in 2006 (Department for Transport, 2008a,b). McKinnon and Piecyk (2009) estimate that between 18.6 and 25.8 million tonnes of CO₂ were emitted by UK road freight sector in 2006, depending on the scope of analysis, the nature of the calculation and the assumptions made. The UK Department for Transport (2008b) forecasts that CO₂ emissions from HGVs will increase to around 33 million tonnes by 2020. In contrast to global trends, in the UK HGV activity has grown slower than passenger traffic, and this is forecast to continue through to 2025.

CO₂ accounts for around 96% of GHGs from road transport sector, with methane (CH₄), nitrous oxide (N₂O) and F-gases (CFC-12 + HFC-134a + HCFC-22) constituting the remaining 4% (Kahn Ribeiro et al., 2007, Choudrie et al., 2008). Thus, the focus of this thesis is on the CO₂ element.

In response to the climate change threat, international and national governments increasingly set GHG emission reduction targets (e.g. UK Climate Change Bill 80% by 2050, EU by 20% by 2020, all relative to 1990 emission levels). As road freight transport is one of the important contributors to CO₂ emissions, it has been identified as one of the areas where improvements should be sought (Committee on Climate Change, 2008). Further, transport and distribution systems have significant life spans and can take a long time to change. Thus, to reduce logistics- and transport-related CO₂ emissions and avoid the worst effects of climate change, immediate action and early planning is required (Lenzen et al., 2003).

³ 1Btu = 2.931×10^{-4} kWh (kilowatt hours)

2.5.2. Other environmental impacts of road freight transport

Noise and vibrations

The environmental impacts of traffic noise differ from those of GHGs or air pollutants in the fact that most of the noise effects are restricted to the time of emission (Doll and Wietschel, 2008). However, road traffic noise tends to be continuous and thus considered a more serious problem than noise caused by other transport modes (for instance railway or aircraft noise), which are intermittent (Gubbins, 1996). Adverse effects of traffic noise include annoyance, communication problems, sleep disturbance and problems with concentration. Prolonged exposure to traffic noise may result in physiological effects such as cardiovascular diseases or irreversible loss of hearing, as well as in mental health problems (Den Boer and Schroten, 2007). Traffic noise also has an adverse effect on residential property values and rents (Forkenbrock, 1999). According to Watts et al. (2006), in the UK “over 90% of the population hear traffic noise whilst at home and about 10% regard their exposure to this source of noise as highly annoying” (p.1). This, however, relates to all traffic and HGVs are only one of the sources of the problem.

Heavy goods vehicles generate three types of noise (Hickling, 1998, Sandberg and Ejsmont, 2002):

- **Propulsion noise** (engine, powertrain, exhaust and intake systems) – a dominant source of noise at lower speeds (under 50 km/hr for HGVs).
- **Tyre / road contact noise** (rolling noise) – this is the main source of noise in lorries at speeds above 50 km/hr.
- **Aerodynamic noise** – this increases as speeds increase and can be reduced by aerodynamic profiling of a vehicle.

The noise performance of HGVs has improved significantly since the mid-1970s (Figure 2.11), mostly due to tighter regulatory controls on new vehicles and retrofitting older trucks with noise mitigation devices. Infrastructural measures, mainly resurfacing of roads with porous asphalt, also were effective in reducing noise associated with road transport. Further noise reductions of up to 5 dB(A) were applied to HGVs after 1996 (DETR, 1999).

It needs to be mentioned here that, in some situations there are trade-offs between reducing noise and reducing other environmental impacts. For instance, Cooper et al. (1994) list a 24-hour lorry operation as one of the ways to reduce fuel consumption and CO₂ emissions. This, however, may increase noise irritation at night, particularly in residential areas. Hence, a decision needs to be made as to which environmental and operational aspects are given priority and, as a result, noise may limit the scope for a night-time delivery that would reduce CO₂ emissions.

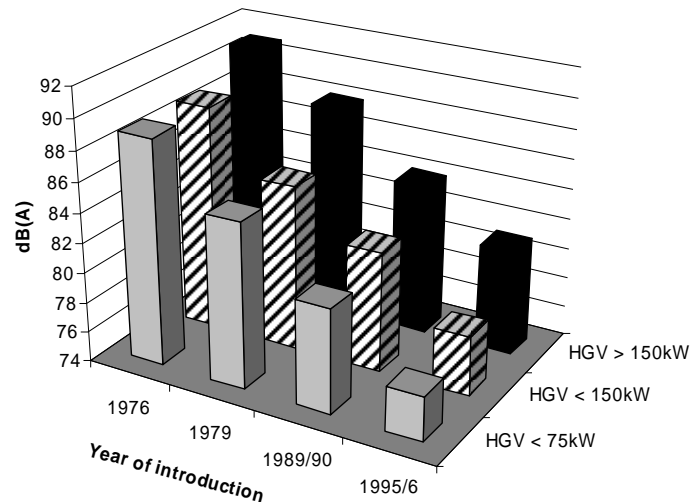


Figure 2.11. Vehicle noise limits
Source: DETR, 1999

Apart from noise, vibration caused by heavy vehicles may result in serious damages to residential properties, historic objects and other buildings (Doll and Wietschel, 2008). Sharp and Jennings (1976) differentiate two types of damage to buildings that can be caused by traffic-related vibration:

- **Architectural damage** – it relates to cracking of plaster and other brittle material, which can be annoying to property owners but does not pose a risk on the structural safety of the building.
- **Structural damage** – it implies that the building itself is in some kind of danger.

According to Wardroper (1981), lorry traffic causes two types of vibrations:

- **Airborne (low frequency) vibrations** – they easily penetrate windows and walls causing objects to rattle on shelves and / or floors to vibrate under people's

feet. However, they would reach “an intensity beyond human tolerance” (p.98), before the level at which minimal architectural damage is caused.

- **Groundborne** vibrations – these can be harmful to buildings even when they are barely perceptible. They may cause serious damage as pressures are redistributed below ground and exert largely intensified impact at foundation level. Groundborne vibrations can cause architectural damage at the level when they are “strong enough to annoy householders” (p.98). When they reach the point of being “unpleasant” they can cause structural damage as well.

Vibration from road traffic can be reduced by improved suspension and tyres. However, as “vibration from road traffic is a result of fluctuations of wheel contact load which are caused by their passage over road surface irregularities or discontinuities in the road profile (..), the best way of minimizing traffic-induced vibration would appear to be the maintenance of smooth road surfaces” (Sharp and Jennings, 1976, p.139).

Land use and biodiversity

Transport activity has also an impact on land use. Land is being taken for development of infrastructure and extraction of road-building materials (Button, 1990). Roads also cause both a direct and an indirect loss of habitat. The direct loss refers to the physical presence of a road and its verges and the conversion of the original land cover into an artificial surface. The indirect loss refers to the fragmentation and / or degradation of ecosystems due to the presence of transport infrastructure, which reduces the capability of an ecosystem to sustain its original biodiversity (Geneletti, 2003).

Waste

Waste associated with road transport includes for example waste oil or scrapped road vehicles themselves. In a wider perspective, it also includes abandoned spoil tips and rubble from road works (Button, 1990). Giannouli et al. (2007) developed a model for the evaluation of waste produced from road vehicles, both during vehicle operation and at their end-of-life disposal. The modeling results indicate that the UK is the second largest contributor, after Germany, to annual waste arising from in-use and end-of-life vehicles in EU-15. It was estimated that annual vehicle-related waste produced in four countries responsible for the vast majority of the total waste from road transport (Germany, UK, France and Italy) is going to increase from around 14 million tonnes in 2000 to over 21 million tonnes in 2020. Further, more than 70% of the overall annual

waste from road transport is produced from end-of-life vehicles, with ferrous parts being a predominant source of waste from the scrapped vehicles (66% of the total). Tires and operating liquids are the two biggest components of the in-use waste (43% and 35% of the total in-use waste, respectively). Unfortunately, although the model differentiates between road vehicle categories, the detailed results for HGVs are not presented separately.

2.5.3. Other transport-related impacts

Transport also poses two other substantial challenges to long-term sustainability. These are congestion and accidents. Although these cannot be considered as environmental impacts *sensu stricto*, but they account for a large proportion of the external costs of road freight transport.

Congestion

According to Goodwin (2004), “congestion is defined as the impedance vehicles impose on each other, due to the speed-flow relationship, in conditions where the use of a transport system approaches its capacity” (p. 7). Hence, a vehicle cannot be driven at speed, that it would have been driven at in free-flow traffic conditions.

Congestion results in time losses and causes additional direct operating costs for road transport users (Piecyk and McKinnon, 2007). It also contributes to excessive fuel use and, thus, to increased CO₂ and air pollutants emissions. According to Doll and Wietschel (2008), 10% of congestion costs can be attributed to negative environmental impacts of increased fuel consumption. Figure 2.12. shows the impact of vehicle speed on CO₂ emissions per vehicle kilometre (based on an example of articulated vehicle over 40 tonnes gw). As can be seen, driving at speed lower than 30 km/hr causes significant increase in fuel consumption and CO₂ levels emitted per vehicle-km.

Road freight transport contributes to congestion to a lesser extent than passenger travel. In a study concerned with food distribution in the UK, it was estimated that cars contribute 50% of the total social costs associated with congestion, while HGVs generated only 27% of this total (Smith et al., 2005). Further, the logistics sector is one of the most affected by congested infrastructure. Within the area of transport and distribution, congestion can impose adverse effects on economic efficiency and

competitiveness by increasing costs and reducing the reliability of logistics schedule (McKinnon, 1998a, McKinnon et al., 2008a).

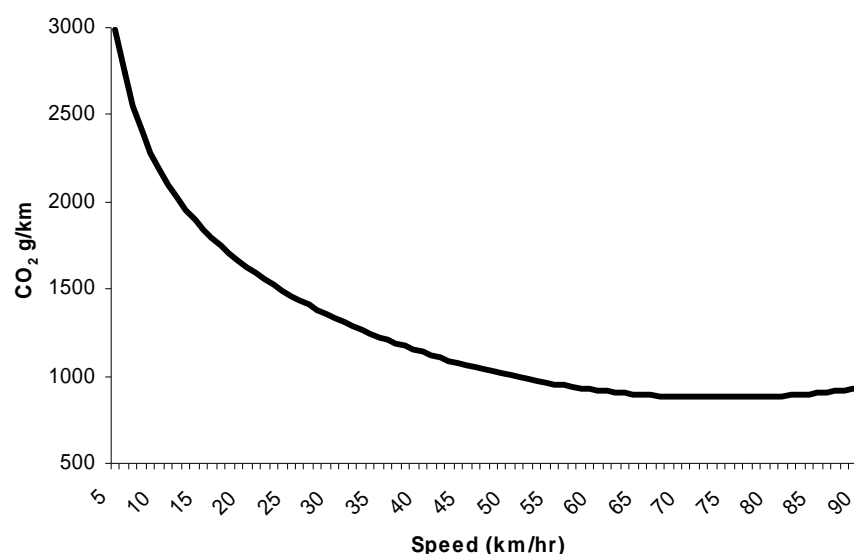


Figure 2.12. Vehicle speed and CO₂ emissions – articulated vehicle over 40 tonnes gvw
Source: Test-cycle data supplied by Department for Transport

Accidents

Transport results in many fatalities and serious injuries each year. In 2007, 10,688 HGVs in Great Britain were involved in 9,829 road accidents. 127 people were killed and 461 seriously injured in road accidents involving HGVs (Department for Transport, 2008c). Apart from personal injury, death or material losses for those involved, accidents cause delays and general inconvenience for other road users. They also amplify the effects of congestion (McKinnon, 1998a).

Rate per 100 million vehicle-kms	Cars	HGVs	All motor vehicles
Fatal	0.8	1.6	0.9
Fatal or serious	7.5	6.6	8.4
All severities	63	36	62

Table 2.2. Accident involvement rates: by vehicle type and severity of accident (2007)
Source: Department for Transport, 2008c

Although HGVs have a lower overall frequency of involvement in traffic accidents, there is a significantly higher probability of them being involved in a fatal accident (Table 2.2) as compared to other motor vehicles. This reflects the fact that trucks travel mostly on major roads (87% of the total vehicle-kms traveled by HGVs in 2007) at relatively high speeds (Department for Transport, 2008d) and have greater momentum, due to their greater weight.

Visual intrusion

One of the minor social impacts of HGVs is their visual intrusion. It means that the presence of lorries spoils the surrounding landscape and/or outlook from residential properties. Visual intrusion is difficult to measure because it is a highly subjective factor. It is generally assumed that its impact will be greater in “more beautiful and historic urban landscapes of Britain” (Sharp and Jennings, 1976, p.142). Two surveys of public responses to different sizes of lorry conducted by the Transport and Road Research Laboratory have shown that no clear preferences could be established (Rosman, 1976). The study used one HGV of 16 tonnes, two of 8 tonnes and four of 4 tonnes carrying capacity in order to investigate if one of the combinations can be proven to be more acceptable than the others. Size of the vehicle was identified as the second most bothering factor, after noise, for the participants. However, it is not clear if the term size is directly interchangeable with visual intrusion. Sharp and Jennings (1976) conclude that, as “there is no obvious way in which vehicles can be made more beautiful or aesthetically acceptable”, the only solution would be to designate alternative routes for HGVs to follow (p.142).

2.6. Measuring the Environmental Impact of Transport

Measuring the environmental impact of transport is a complex exercise and there are multiple approaches that can be followed for the assessment. The UK government uses two broad categories to present environmental impact data. ‘Source’ figures include only direct emissions from the sector for which the inventory is compiled. ‘End user’ or ‘well to wheel’ figures include both ‘source’ emissions and emissions from upstream sources, i.e. a share of emissions from power stations, refineries or other fuel-processing plants allocated back to the end user based on their fuel consumption. For the CO₂ emissions from the transport sector, the ‘end user’ category adds around 20% to the ‘source’ total (Commission for Integrated Transport, 2007, Woodcock et al., 2007).

‘Source’ emissions from road transport can be divided into the following categories (Environmental Protection Agency, 1994, Krzyzanowski et al., 2005):

- **Exhaust (tailpipe) emissions** – including cold-start and hot emissions. Cold-start emissions are emitted after engine start-up before the emission control equipment reaches its optimal operating temperature. The term hot emissions is used for exhaust fumes emitted after the vehicle is warmed up, i.e. under

thermally stabilised engine operation. Cold-start emissions are higher than hot emissions.

- **Evaporative emissions** - i.e. direct fuel evaporation. Evaporative emissions are important for petrol and gas fuelled vehicles, due to these fuels volatility. Diesel fuel is heavier and oilier than petrol, which makes it more stable. As a result, although evaporative emissions are an important source of non-methane hydrocarbons from road transport, they arise primarily from passenger traffic.
- **Fugitive emissions from tyre and brake wear** – these are non-exhaust particulate matter (PM) emissions produced by wear on vehicle components (tyres, brakes and clutch) and road abrasion.

From this classification it can be concluded that for the road freight transport sector tailpipe CO₂ emissions equal ‘source’ CO₂ emissions.

‘End user’ or ‘well to wheel’ approach provides a comprehensive estimate of emissions associated with direct and upstream emissions from the transport sector. Life Cycle Assessment (LCA) goes even further in environmental impact assessment. LCA is defined as a ‘cradle to grave’ technique that considers the entire life cycle of a product, service or process from extracting raw materials to recycling or final disposal (United Nations Environment Programme, 1996, Miettinen and Hamalainen, 1997, Browne et al., 2005). LCA is a complex and time-consuming process. According to Browne et al. (2005), full LCA should include “a detailed description of raw materials and energy inputs used at all points in the life of the product. It will also include detailed analysis of a range of emissions (such as pollutants, noise and odours), effluent and solid waste outputs, and material and energy resource depletion” (p.762). Hence, for road freight sector LCA should include environmental impacts related to production, use, maintenance and disposal of vehicles, extraction, production and burning of fuel or even impacts arisen through provision and maintenance of transport infrastructure (Facanha and Horvath, 2006).

Spielmann and Scholz (2005) provide a comprehensive life-cycle inventory for road, rail and waterborne freight transport in Europe. Their results suggest that emissions from HGV travel constitute the largest proportion of the total life cycle-emissions from road freight sector. Eriksson et al (1996) also examined the sector from a life-cycle perspective. They conclude that the main environmental burden related to road freight

transport arises from using the vehicles, mainly from burning diesel fuel. The production and after use treatment of the vehicle has a smaller contribution to the environmental impacts, mostly due to the large distance travelled throughout a life-span of an average lorry. A study conducted by Gaines et al. (1998) confirmed the conclusion that direct impacts of the vehicle and fuel production contribute only modestly to the total energy use and GHG emissions associated with HGVs, measured on the life-cycle basis. The largest proportion of environmental impacts is attributed to operating the vehicle, i.e. mostly fuel use. The main reasons for this were long distances travelled by lorries at low fuel economy. Facanha and Horvath (2007) also conclude that burning diesel fuel is the dominant life-cycle phase for CO₂ emissions from road freight transport, even when infrastructure construction works are included in the calculations.

Life-cycle approach monitors the environmental effects of complete energy systems, giving the most comprehensive base for comparison of different options. Hence, it is particularly relevant in the assessment of alternative transport policies, for instance switching to alternative fuels, assessment of transport infrastructure planning etc. (Heseltine and Nelson, 1996, Facanha and Horvath, 2007). However, most of the upstream factors are beyond control of the logistics industry. Thus, the usability of life-cycle or 'end user' approach is very limited in a study aiming to forecast BAU trends from the road freight transport representatives' perspective. Since decisions and operating practices of supply chain members will have an effect on fuel consumption and thus on direct CO₂ emissions rather than on upstream processes, 'source'/tailpipe emissions are better suited measure for the purpose of this study. Further, life cycle and 'end user' figures are subject to more uncertainty than 'source' figures because of the averaging needed to allocate the upstream impacts to final assessment categories. Thus, although the importance and advantages of life-cycle or 'end user' approaches are recognised, the focus in this thesis is on direct 'source'/tailpipe CO₂ emissions.

2.7. Conclusions

Freight transport plays a vital role of keeping end consumers supplied with goods and services. The ability to supply society with food, energy, construction materials and other goods, promotes regional and national growth and development. On a global scale, freight transport supports international trade and allows countries to develop their economies which leads to higher incomes, standard of living and quality of life for the citizens. Road freight transport has the advantage of being the most flexible of all

freight carrying modes (WBCSD, 2002). However, it also has various negative impacts on the environment in terms of energy consumption, land use, water and soil pollution, local air quality, noise and climate change. The environmental impact of road freight transport is receiving increased attention. This can be in the form of increased restrictions on operating methods, as well as in technical aspects of vehicle design.

Green logistics is emerging as a sub-discipline at a time when the traditional principles of logistics and supply chain management are becoming ever more influenced by sustainability concerns, leading to increasing interaction between transport and distribution systems with environmental science. Hence, the basic principle of green logistics is to fuse the economic approach and the ecological approach and in doing so create a long-term logistics solution. It is widely recognised, both by researchers as well as practitioners, that making environmental improvements is often the best way to increase a company's efficiency and, therefore, profitability. A more proactive approach of green logistics management instead of reactive compliance with regulations is now perceived as one of the main sources of long-term competitive advantage.

However, it is important to remember that logistics and transport decisions closely interact with other organisational functions (McIntyre et al., 1998). "Since transport plays an important role in logistics and the supply chain, an analysis of its nature, volume and pattern must be rooted in an understanding of the way the whole supply chain functions" (Yang et al., 2005, p.193). Although minimising the environmental impact of transport is important, it should not be considered in isolation. There may be trade-offs involved where minimising the impact of some processes may increase the impact of other activities. One example is newspaper production where changing the location of manufacturing facilities increases the CO₂ emissions from transporting the product, but reduces its overall carbon footprint⁴ (Carbon Trust, 2006). The ultimate objective should be to minimise the total environmental impact of the whole supply chain. "We must recognise that lorry operation is a consequence of logistics planning, and that until the objectives of logistics planning are understood, attempts to control the growth of lorry traffic in the interest of the environment are unlikely to succeed" (Cooper et al., 1994, p.271). This research aims to link the consequences of choices

⁴ Carbon footprint can be defined as the total amount of CO₂ and other GHGs (expressed as CO₂e) emitted over the entire lifecycle of a product or service. At a supply chain / company level it can be defined as the total amount of GHGs (in CO₂e) emitted by this supply chain / company over a given period.

made at different levels of organisational decision-making hierarchy to changes in key parameters determining the level of road freight transport activity and related CO₂ emissions.

It is worth noting also that apart from a central issue of reducing the environmental burden of transport, reversal of causality is already emerging as a research theme. The problem of the consequences of climate change and changing weather conditions for the transport sector is likely to receive increased attention in the future research. The US Transportation Research Board has already published a report on likely consequences of changing climate conditions to US transport system (Transportation Research Board, 2008). Changing climate may affect freight transport on both supply and demand sides. Supply may be affected at short notice when for instance extreme weather conditions force logistics operators to stop or modify their transport. In the longer term, supply side adjustments may be needed in the design of infrastructure or vehicles to cope with adverse weather conditions, for example heavy wind. On the demand side, “trade flow patterns will be affected by climate change in the long run when climate change affects location patterns of production and consumption. In a similar vein seasonal variations may occur. Further, freight transport will be affected when climate or weather changes lead to changes in generalised costs of transport, directly or indirectly” (Koetse and Rietveld, 2009, p.206). Climate change and adverse weather conditions may further increase CO₂ emissions from road freight transport in many ways, most of which are very difficult to predict. However, as mitigation and adaptation measures are clearly interrelated, the adaptation strategies are likely to become an emerging theme within the field of green logistics.

Chapter 3. Factors Influencing CO₂ Emissions from Road Freight Transport

Aims of the chapter:

- *To review relevant literature and identify areas that require further investigation*
- *To examine statistical trends in key parameters*
- *To introduce the theoretical framework underpinning the empirical research*

In Chapter 2 the basic concepts of freight transport, logistics and supply chain management were defined. It also introduced the concept of sustainable development and presented the magnitude of environmental problems associated with road freight transport. This Chapter provides an overview of the published literature related to the main research areas covered in this work. It focuses specifically on the factors determining the CO₂ emissions from road freight transport sector.

In the first part, the relationship between economic performance, road freight demand and related externalities is investigated. The available literature on the key logistics variables shaping this relationship is then reviewed. A range of factors likely to exert influence on CO₂ emissions from HGV activity is identified. This leads to the development of a conceptual framework underpinning this research project, which concludes the Chapter.

All statistics presented in this Chapter are based on the GB-registered HGV vehicles, i.e. include HGVs registered in England, Scotland and Wales and exclude the ones registered in Northern Ireland, unless otherwise specified. This is due to a very limited availability of freight statistics for Northern Ireland (Department for Regional Development, 2009). As tonnes lifted in Northern Ireland accounted for between 3.3 and 3.9% of the UK total for the years 2003 to 2007 (Department for Regional Development, 2009, Department for Transport, 2009a), the share of Northern Irish road freight transport can be considered marginal and excluded without any major distortion of statistics presented in this thesis. The data presented in this thesis excludes also freight movements in vans.

3.1. Factors Influencing the Environmental Performance of Road Freight Transport

CO₂ emissions from road freight transport are directly related to the type and amount of energy used by HGVs (Piecyk, 2010, Leonardi et al., 2006). As virtually all HGVs are diesel powered, the energy use equates directly to the amount of diesel fuel consumed. For every litre of diesel burnt 2.6391 kilograms of CO₂ are emitted to the atmosphere (DEFRA, 2009). Energy use, in turn, is driven by the demand for road freight transport, which in the past has been quite closely related to the economic growth (Sorrell et al., 2009, Tapio, 2005, McKinnon, 2007a). Thus, on a macro-level, the trend in CO₂ emissions is underpinned by the relationship between the volume of road freight movement and economic growth. This relationship can be then broken down into a series of aggregate logistics-related values and key variables, giving a micro-level perspective on the problem. These relationships are investigated in the next sections.

3.2. Demand for Road Freight Transport

Road freight transport activity in GB is recorded by the Continuing Survey of Road Goods Transport (CSRGT), conducted annually by the UK Department for Transport. The CSRGT provides statistics on the UK activity of GB-registered lorries. The survey is based on a weekly sample of approximately 300 - 350 HGVs selected from the Driver and Vehicle Licensing Agency (DVLA) database. The vehicle operator is asked to record data about one week's activity from a selected vehicle. The data received is then grossed up to produce the national totals. As the sample is spread evenly throughout the year, it is 'self weighting' in respect of seasonal differences in intensity of road freight transport activities (Department for Transport, 2007a, 2009a).

Figure 3.1. shows the trends in tonne-kms, tonnes lifted and vehicle kms between 1980 and 2008. Vehicle kms represent the total distance travelled by HGVs in a given year. Tonnes lifted are derived by adding together the weight of all the loads carried. Tonne-kms are derived by multiplying the weight of a load by the distance over which it was hauled (Department for Transport, 2009a).

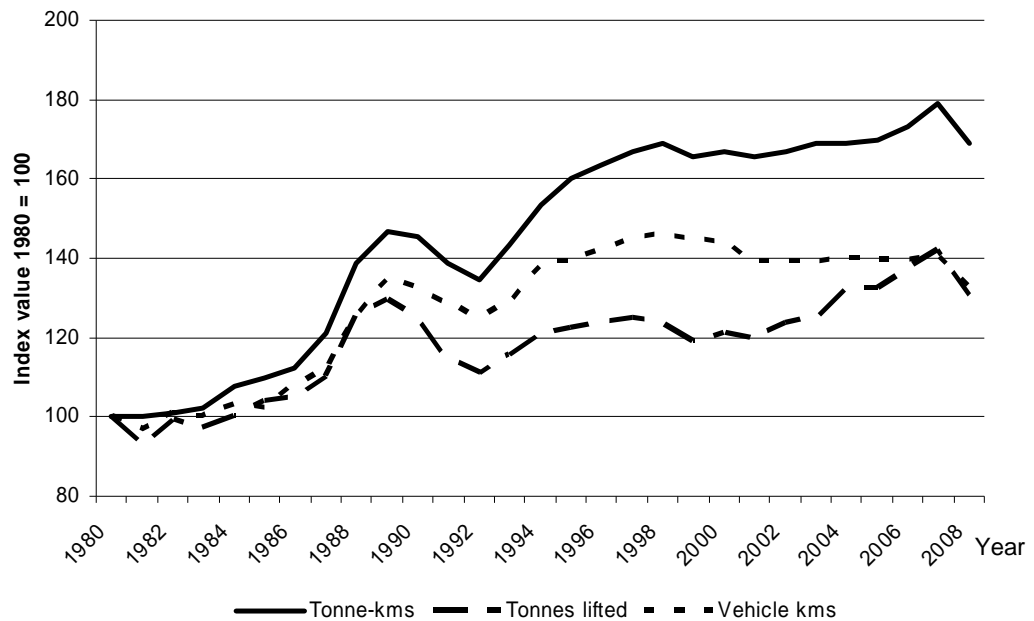


Figure 3.1. Trends in tonne-kms, tonnes lifted and vehicle kms, 1980 – 2008
Source: Department for Transport, 2009a

There were 90 billion tonne-kms performed by HGVs in 1980. This had been increasing until 1990, when the freight transport activity contracted following the economic downturn in early 1990s. Since 1992 the road freight tonne-kms rose again until 2007, when they peaked at 161 billion. Tonnes lifted and vehicle kms had followed a very similar pattern until early 2000s. The total distance travelled by lorries has stabilised since then, while tonnes lifted have continued to grow until 2007. The 2008 data for all indicators show a downward change from 2007, most likely resulting from a recent slowdown in the economic growth (Department for Transport, 2009a, Office for National Statistics, 2009a). Overall, between 1980 and 2008 tonne-kms rose by 69%, tonnes lifted by 31% (from 1.3 to 1.7 billion) and vehicle kms by 33% (from 16 to 21 billion). As freight transport activity is intensifying, negative social and environmental impacts associated with it are very likely to worsen too. Hence, it is important to understand the underlying causes of this growth to improve the overall sustainability of freight transport sector in the future.

3.3. Economic Activity and Road Freight Traffic Growth

Historically, there has been a close relationship between economic growth (typically measured as Gross Domestic Product (GDP)) and freight transport growth (Schleicher-Tappeser et al., 1998, Banister and Stead, 2002, Tapio, 2005, Tapio et al., 2007). GDP measures the total value of the final output of goods and services produced in the economy over a specified period. GDP is a sum of consumption, investment,

government purchases and net exports (Mankiw, 2007). Freight transport volume is expressed in tonne-kms as this composite measure takes into account both weight of goods moved and distance over which they travel (McKinnon et al., 2008b).

The underlying rationale used to explain the relationship between GDP and freight volumes often refers to the fact that transport is generated by other economic activities and, as such, can be described as ‘a second-order activity’ or a derived demand (Ruijgrok, 2001, Pastowski, 1997). Thus, changes in production and consumption of goods and services will determine the demand for freight transport. Numerous attempts have been made to explain or predict freight demand using various economic and industrial indices based on an assumption that changes in freight volumes will most likely lag behind and be attributable to changes in one or more such indices (e.g. Fite et al., 2002, Lyk - Jensen et al., 2005, Kveiborg and Fosgerau, 2007, Lu et al., 2007, Sorrell et al., 2009). A cross-sectional study of a sample of thirty-three countries at different stages of development undertaken by the World Bank using 1989 data found that differences in GDP explained 89% of the variation in road tonne-kms (Bennathan et al., 1992). While economic growth increases the welfare of a country, externalities associated with road freight transport reduce that welfare. Thus, the question of how a country can experience economic growth without facing the negative side effects of transport growth is receiving increasing attention (Ballingall et al., 2003). This highly desired ability of an economy to grow without a corresponding increase in road freight transport activity is commonly referred to as ‘decoupling’.

A number of studies have investigated the degree of decoupling of GDP and transport growth in Europe (e.g. Meersman and Van de Voorde, 2002, Tapio, 2005, Leonardi et al., 2006, Tapio et al., 2007, Verny, 2007), in the US (Banister and Stead, 2002), New Zealand (Ballingall et al., 2003) and Asia (Lu et al., 2007). The predominance of the European perspective on the problem can be explained by the fact that while there are significant signs of the decoupling in the US (Banister and Stead, 2002), in the EU road freight traffic continues to grow at much faster rate than GDP (McKinnon, 2007a), creating the need for further investigation into opportunities to reverse this relationship.

3.3.1. Types of decoupling

According to a report prepared by the Organisation for Economic Co-operation and Development (OECD, 2006), there are two broad categories of decoupling:

- **Absolute (strong) decoupling** occurs when GDP displays positive growth and the transport growth rate is zero or negative. This decoupling is quite uncommon in practice.
- **Relative (weak) decoupling** occurs when the transport growth rate is positive but is less than the GDP growth rate.

Verny (2007) also distinguishes absolute and relative decoupling but defines the two types in a slightly different manner. While in the case of absolute decoupling the attention is focused on minimising the total demand for freight transport, the relative decoupling can be achieved by shifting freight to different transport modes (e.g. from road to rail).

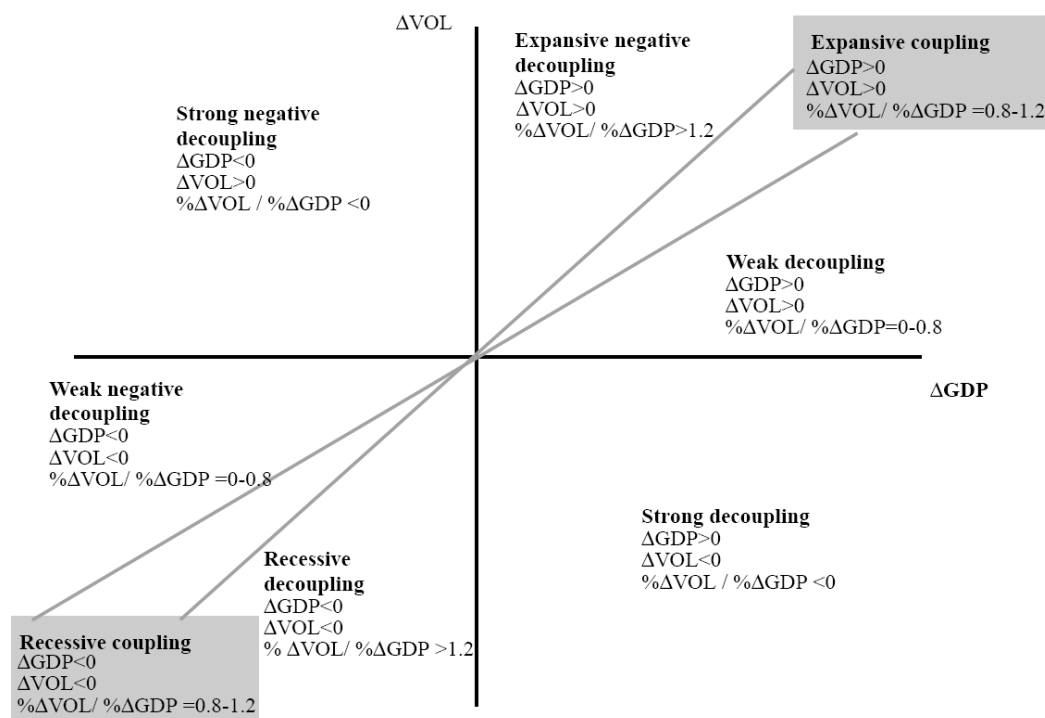


Figure 3.2. The degrees of coupling and decoupling of GDP and transport growth
Source: Tapio, 2005

Tapio (2005) presents the most comprehensive framework of the different aspects of decoupling (Figure 3.2). According to this framework, the growth of GDP and transport volumes can be coupled, decoupled or negatively decoupled. Elasticity values (i.e. the percentage change in transport volumes divided by the percentage change in GDP) of

0.8 – 1.2 are regarded as coupling ($\pm 20\%$ variation margin in the elasticity values has been introduced “in order not to overinterpret slight changes as significant” (p.139)). Also, “the growth of the variables *per se* can be positive or negative, expressed as *expansive coupling* and *recessive coupling*. Decoupling can be further divided to three subcategories: in *weak decoupling*, GDP and transport volume both increase (and $0 < \text{elasticity} < 0.8$), *strong decoupling* occurs when GDP grows and transport volume decreases (and $\text{elasticity} < 0$) and *recessive decoupling* when GDP and transport volume both decrease (and $\text{elasticity} > 1.2$). Similarly, negative decoupling includes three subcategories: in *expansive negative decoupling* GDP and transport volume both increase ($\text{elasticity} > 1.2$), in *strong negative decoupling* GDP decreases and traffic volume increases ($\text{elasticity} < 0$) and *weak negative decoupling* occurs when both variables are decreasing ($0 < \text{elasticity} < 0.8$)” (pp. 139 – 140).

Tapio (2005) and Tapio et al. (2007) develop the theory of decoupling further and introduce three forms of decoupling:

1. **Decoupling of transport volume growth from economic growth** (referred to as immaterialisation, qualitative growth or structural change), where the elasticity value expressed as the percentage change in transport volumes divided by the percentage change in GDP over a specified period is less than 1 ($\% \Delta \text{VOL} / \% \Delta \text{GDP} < 1$)
2. **Decoupling of transport CO₂ emissions from transport volume** (referred to as dematerialisation, eco-efficiency or technical development), where the elasticity value expressed as the percentage change in transport CO₂ emissions divided by the percentage change in transport volumes over a specified period is less than 1 ($\% \Delta \text{CO}_2 / \% \Delta \text{VOL} < 1$).
3. **Decoupling of transport CO₂ emissions from economic growth** (referred to as decarbonisation, de-linking and different factor concepts), where the elasticity value expressed as the percentage change in transport CO₂ emissions divided by the percentage change in GDP over a specified period is less than 1. ($\% \Delta \text{CO}_2 / \% \Delta \text{GDP} < 1$).

The two last forms of decoupling are very much interrelated and, thus, sometimes referred to interchangeably. For example, Ausubel, (1995) presents the concept of decarbonisation as a case of dematerialisation. Figure 3.3. illustrates the relationships between the three theoretical forms of decoupling. It suggests that in order to improve

the overall sustainability of road freight transport, the efforts should not be solely focused on the decoupling of GDP and road tonne-kms relationship. Measures designed to break the link between transport volumes and CO₂ emissions (e.g. use of alternative fuels or switching to alternative transport modes) or between GDP and transport sector CO₂ are equally important and should be receiving more attention in the literature.

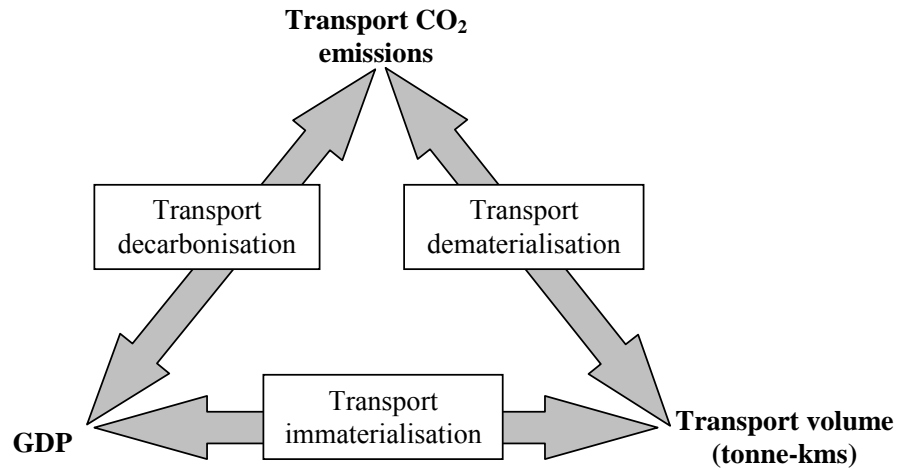


Figure 3.3. The concepts of transport decarbonisation, dematerialisation and immaterialisation
Adapted from: Tapio et al., 2007

As decoupling of freight is defined generally as a reduction of freight transport activity per unit of GDP, sometimes it is referred to using the term transport intensity. According to Tight et al. (2004), the transport intensity as a concept was initially developed by Peake (1994), who adapted it based on an analogy with the energy sector. Peake (1994) defines transport intensity in terms of how efficiently transport is used in production and consumption, i.e. what volume of transport is required per unit of economic output (i.e. tonne-kms / GDP). Similarly, Piecyk and McKinnon (2009a) express freight transport intensity as tonne-kms per unit of GDP and review the trends for a wide range of countries around the world. Lakshmanan and Han (1997) conduct a review of the US data while Ahman (2004) applies a similar approach in Sweden. Stead (2001) argues that transport intensity can be assessed using two types of measures: transport energy efficiency (i.e. energy consumption per tonne-km) and economic efficiency (i.e. GDP / tonne-km). Independently on the configuration used, the concept of reducing transport intensity is synonymous with the one of decoupling and these two can be used interchangeably.

3.3.2. Decoupling of GDP and road freight transport growth in the UK

In terms of freight transport in general, the UK case is different from the situation in the European Union as a whole, where there is a continuous strong link between freight transport demand and GDP and, in fact, in some of the countries freight transport is growing at a much faster rate than GDP (Tight et al., 2007). According to Tapio (2005), in the UK there was expansive negative decoupling in 1970s, expansive coupling in 1980s and a weak decoupling of freight transport and GDP since mid-1990s. McKinnon (2007a) calculated the GDP / freight transport elasticity value of 0.37 between 1997 and 2004, which is consistent with Tapio's definition of weak decoupling.

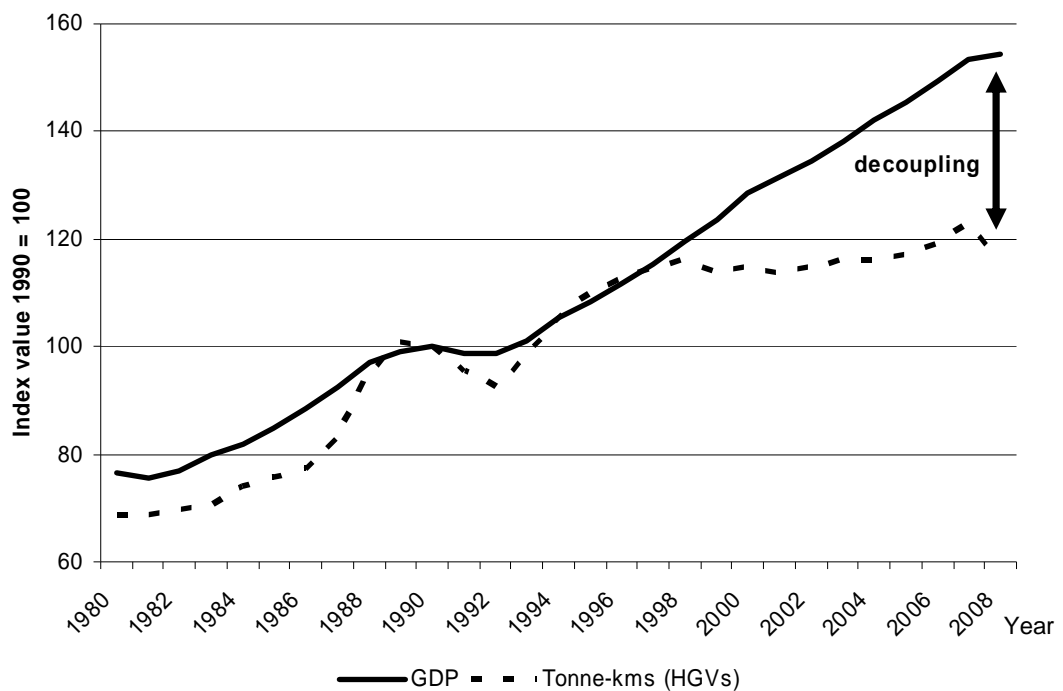


Figure 3.4. Decoupling of economic growth and road freight transport
Source: Department for Transport, 2009a, Office for National Statistics, 2009a

Figure 3.4 shows the relationship between UK GDP and road freight movements. This figure may be subject to a marginal inaccuracy as the GDP data is recorded for the UK as a whole whereas the road freight transport data refers to the GB-registered truck activity in the UK. Overall, this relationship was relatively stable until the late 1990s. The recent experience, however, suggests that there has been a pronounced decoupling of economic growth and the growth in road freight movement. Between 1997 and 2007, GDP rose by 33% in real terms while road tonne-kms grew by only 7% (Department for Transport, 2009a, Office for National Statistics, 2009a). If this decoupling were to continue, it would indicate a long-term structural change in the UK economy, in which increasing national prosperity would not generate a proportional increase in freight

traffic volumes. Stabilisation and subsequent reduction in freight-related externalities would help to promote the sustainable development policy and sustainable logistics strategy advocated by the British Government and European Union (DETR, 1999, European Commission, 2001, 2006, Department for Transport, 2008b, 2009c). The potential for decoupling economic growth has been recognised and promoted by the Government over the last decade (e.g. SACTRA, 1999). Nonetheless, it is questionable if this trend is going to endure, as recent evidence suggests that expectations of the long-term decoupling may have been premature as in 2007, after more than 10 years in which the annual growth rates for road tonne-kms were lower than that of GDP, the two rates converged again at 3% (McKinnon et al., 2008b). Also, the effect of the recent economic downturn is already visible in 2008 road freight traffic data, leading to a case of strong decoupling in that year. It is most likely to affect also data sets in the nearest future, temporarily distorting longer-term trends and resulting in the situation of weak negative decoupling, recessive coupling or recessive decoupling.

McKinnon et al. (2008b) also show how changing the year used for indexing GDP and road freight data can affect the extent of the apparent decoupling and recoupling. Analysing the data for the period between 1980 and 2007, the authors demonstrate how rebasing figures for different intervening years affects the start year and magnitude of the decoupling trend. The need for careful interpretation is emphasised as “using 1990 (as a base year) makes the divergence of the two trends since 1997 seem quite pronounced, while using 2003 as the base year makes it appear a minor blip. Rebasing the figures against the later years has the effect of magnifying the positive decoupling of the tonne-kms trend during the 1990s- that is, tonne-kms increasing faster than GDP- making the negative decoupling during the 2000s look like a short-term rebound” (p.41). Based on these results the authors emphasise that any conclusions should be drawn with caution as the interpretation of the recent developments in the decoupling trend is subjective and can be easily manipulated by the way the graphs are drawn. However, independently of the base year used, in all cases the decoupling of GDP and road freight transport growth in the UK has been clearly visible, though with varying intensity and/or start date. Thus, the presence of the decoupling trend cannot be questioned, although its potential to contribute to the long-term environmental sustainability of road freight transport remains uncertain.

3.3.3. Possible reasons for decoupling

McKinnon (2007a) identifies 12 possible causes of the decoupling of GDP and road freight transport in the UK and assesses their relative significance. The possible reasons discussed are as follows:

- 1. Change in the systems of statistical accounting** – the changes to the methodology of economic and transport surveys could distort the relationship between the two variables.
- 2. Dematerialisation**, i.e. “the reduction of material resources needed per unit of GDP”, as defined by Schleicher-Tappeser et al. (1998, p. 4) – this can be a result of declining weight of goods in the economy, increasing their value or a combination of these two trends. However, Kveiborg and Fosgerau (2007) report that based on their research in Denmark, “changes in the composition of commodities within industries and the weight to value ratios (the inverse value density) do not seem to contribute significantly to the development in road freight transport or road freight traffic” (p.40).
- 3. Change in the composition of GDP** – typically, services generate fewer road tonne-kms relative to sales revenue than sectors that produce and distribute tangible goods. Thus, the increasing share of service activities in the GDP composition is likely to contribute to the decoupling of GDP and road freight transport activity. Similarly, Meersman and Van de Voorde (2002) claim that “in Europe, it is not so much growth of GDP that is the driving force behind growth in freight transport, but the increase in industrial output. These two variables do not always evolve proportionately, mainly because economic growth in many European countries is generated by the services sector rather than industry or manufacturing” (p.6).
- 4. Decline in road’s share of the freight market** – shifting freight to other transport modes leads to a “mode-specific” decoupling (or “relative decoupling” in Verny’s (2007) classification).
- 5. Increase in the penetration of the domestic road haulage market by foreign operators** – as foreign registered vehicles are not recorded by the CSRG, freight movements by non-domestic operators on British roads are excluded from the road tonne-km statistics. If the proportion of tonne-kms carried by foreign vehicles was to increase, it would give the illusion of an intensifying decoupling of the GDP and road freight activity.

- 6. Displacement of freight from trucks to vans** – similarly, loads moved in vans lighter than 3.5 tonnes are excluded from the official road tonne-kms statistics. Displacement of freight onto the smaller vehicles will clearly contribute to some of the decoupling of GDP and HGV tonne-km trends.
- 7. Reduction in the average number of links in the supply chain** – structural changes in the supply chain, such as for example vertical disintegration of the manufacturing process, are likely to have an influence on the tonne-km statistic.
- 8. Diminishing rate of spatial concentration** – the spatial concentration of economic activity (for example manufacturing, stockholding, sortation operation etc.) typically leads to an increase in the demand for road freight transport. However, there are limits to which production and distribution systems can become centralised. If the process of spatial concentration was to reach its maximum extent or possibly reverse resulting in more localised supply chain structures, this could result in stabilisation or even reduction in the tonne-kms moved by trucks.
- 9. Improvement in the efficiency of vehicle routing** – developments in Computerised Vehicle Routing and Scheduling (CVRS) software and significant uptake in commercial application of such packages can lead to a reduction of the distance travelled by HGVs and, thus, reduce the tonne-kms statistic.
- 10. Domestic supply chains becoming fully extended** – it is possible that within a mature market such as the UK, domestic supply chains have achieved their maximum ‘logistical reach’ and, thus, road freight transport flows have stabilised.
- 11. Erosion of industrial activity to other countries** – when domestically manufactured goods are replaced by imports from other countries, many of the upper links in the supply chain are also likely to transfer abroad, as new local suppliers of raw materials, parts and components are found. Hence, the overall amount of freight traffic in the ‘offshoring’ country is likely to decrease, even allowing for import journey legs (e.g. from a port of entry) now being longer than the domestic outbound delivery legs from final point of production that they replace.
- 12. Increase in the real cost of road freight transport** – as the real cost of road haulage increases it is likely to depress the demand for lorry traffic.

In the assessment of the relative importance of the causes listed above, McKinnon (2007a) concludes that, based on the available data, it is possible to quantify the contribution of only three of them: increased penetration of UK haulage market by foreign operators, decline in road's share of the freight market and increase in the real cost of road freight transport explained 67% of the observed decoupling (33%, 22% and 12%, respectively). Diminishing rate of spatial concentration and erosion of industrial activity to other countries were also believed to have a 'very significant' impact, while other factors were considered relatively less important, with changes in the systems of statistical accounting not likely to have any impact at all. McKinnon (2007a) also acknowledges that geographical location of a country has a major influence on the likelihood of it achieving a major decoupling of economic growth and road freight transport activity. He emphasises that two countries experiencing the greatest level of the decoupling in Europe - Finland and the UK are both peripheral and, thus, have not experienced the huge increase in transit freight movements occurring in more centrally located states.

In conclusion, McKinnon (2007a) suggests that although the signs of decoupling are encouraging and definitely in the right direction, "the recent decline in the road tonne-km intensity of the UK economy will need to be supplemented by further reductions in empty running, higher vehicle load factors, improvements in fuel efficiency, tightening emission controls and a continuing modal shift to rail and water" (p.61).

3.4. Links between Economic Growth and Demand for Road Freight Transport

Although the signs of decoupling are already visible, there is still a great deal of uncertainty of their long-term durability and magnitude. As freight transport continues to grow, even at a slower pace, the associated environmental problems become more severe. Schleicher-Tappeser et al. (1998) indicate two solutions to this problem: technological improvements and the deceleration of transport growth. They also believe that current technological approaches are not sufficient to mitigate unacceptable environmental impacts, thus the emphasis should be put on preventing further increase of transport volumes. Similarly, Stead (2001) suggests "the current rate of increase in transport volumes is outstripping the rate of improvement in environmental technology for transport, resulting in increasing environmental problems in the transport sector. There is therefore an increasingly strong environmental argument to increase transport intensity (i.e. GDP per tonne-km) in order to reduce pollution, resource use and waste"

(p.29). It is worth emphasising here that Stead's definition of transport intensity is the opposite of that presented by other authors (e.g. Peake, 1994, Lakshmanan and Han, 1997 or Ahman, 2004), thus increasing transport intensity is a desirable development in this case, contradictory to the intuitive understanding of the concept.

At the same time, it is argued that explaining the growth in road freight transport and related CO₂ emissions solely in terms of underlying economic growth or other industrial indices is not sufficient to be able to target the problem effectively. There is a need for a framework providing an understanding of how changes in logistics systems can help to break the link between economic growth and road freight transport-related CO₂ emissions (Voordijk, 1999). Drewes-Nielsen et al. (2003) also suggest that the structure of freight transport growth in Europe has changed in the last few decades and this change relates to "the logistically induced demand for transport, especially the increase in flexibility of the production and distribution structures" (p.295). Thus, there is a strong need to disaggregate the relationship between GDP and road tonne-kms into a series of logistical variables to enable an in-depth analysis of the underlying causes of freight traffic growth (McKinnon and Woodburn, 1996, McKinnon, 1998b).

The first attempt to express the relationship between economic growth and road freight transport demand in terms of a number of key ratios is presented by McKinnon and Woodburn (1996). Using as an example the food and drink sector, the authors present the relationship between the real value of products consumed and exported and the amount of vehicle kms generated by the industry. This framework was further developed in the European Commission-funded REDEFINE (Relationship between Demand for Freight Transport and Industrial Effects) project. The purpose of the REDEFINE project was to examine the relationship between economic growth and the demand for road freight transport in five European countries (France, Germany, the Netherlands, Sweden and the UK). This relationship is determined by seven key ratios, i.e. value density, modal split, handling factor, average length of haul, vehicle carrying capacity, load factor and empty running. These key ratios link road freight traffic aggregates such as road tonnes lifted, tonne-kms or vehicle kms in a way that, "if each of these ratios remained stable, road freight traffic would be perfectly correlated with changes in the value of goods produced. In practice, each of these ratios can vary independently. By estimating changes in each of the key ratios through time, it should be possible to establish how much of the growth of lorry traffic is a function of

economic growth and how much is attributable to logistical changes” (REDEFINE, 1999, p.2). The framework was subsequently adapted in other European projects e.g. Trilateral Logistics Study (TRILOG, 1999), and the Analysis of the Effects on Transport of Trends in Logistics and Supply Chain Management (SULOGTRA, 2000) and, at a micro-level, applied in case study research (Voordijk, 1999).

In a similar vein, Schleicher-Tappeser et al. (1998) identified a range of key factors for developing decoupling strategies, namely the material intensity of the economy, the spatial structure of production, distribution and consumption, the handling requirements of goods and the organisation of transport. On this basis, three strategies for achieving the decoupling are developed, that is “dematerialisation of the economy”, “reducing the spatial range of material flows” and “optimisation of transport organisation”. This is consistent with the framework discussed above.

Fosgerau and Kveiborg (2004) use a model similar to the one presented by McKinnon and Woodburn (1996). The starting point is production activity measured in terms of output value expressed in fixed prices. It is then chained by a number of conversion factors to transport flows measured in vehicle kms.

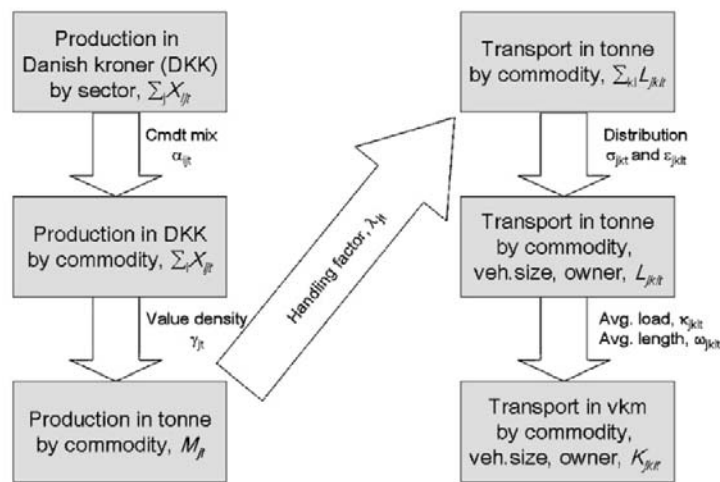


Figure 3.5. Model of the linkage between economic activity and transport flows
Source: Kveiborg and Fosgerau, 2007

The model is then presented in a more elaborated form in Kveiborg and Fosgerau (2007) (Figure 3.5). According to the authors, the boxes correspond to ‘observables’ and arrows between them to ‘transformation factors’. The changes in the transformation factors will cause changes in the observables and, eventually, contribute to the reduction

or growth in freight traffic volumes. In their model, Kveiborg and Fosgerau use industry production values instead of GDP as the economic measure, as “the GDP of an industry is the value of its production less the value of inputs other than capital and labour. Thus GDP is a poor measure of the volume of goods transported, since the whole product is transported, not just that is added by the industry” (p.41). Lehtonen (2006) supports this view arguing that “while GDP is by far the most commonly used measure of economic well-being and the most often used variable to measure decoupling, it is the growth of goods output- not GDP per se- that drives growth in road freight demand” (p.7).

Cooper et al. (1998) introduce a framework linking GDP and vehicle kms in a similar manner to that proposed by McKinnon and Woodburn (1996), but it is then extended to include the environmental effects of HGV activity. It is achieved by linking vehicle kilometres and environmental impacts (defined in terms of CO₂ and other air pollutant emissions) through a series of what the authors call ‘compounding factors’ such as fuel consumption, engine technology and vehicle mix. Although rather crude, this was the first attempt to link economic growth, demand for freight transport and associated atmospheric emissions.

Ahman (2004) does not present a formal framework but suggests that in order to achieve the decoupling of economic growth and CO₂ emissions from road freight transport, the following measures should be used:

- Shifting to non-carbon fuels
- Promoting modal shift to less carbon-intense modes
- Use of more energy efficient vehicles
- More efficient logistics systems
- Shifting to less transport intensive economic growth.

In focusing on these specific areas, Ahman’s approach is similar to the framework presented by Cooper et al. (1998).

Piecyk and McKinnon (2009b) extend and modify the frameworks presented in REDEFINE (1999) and Cooper et al. (1998) to include energy requirements of road freight transport and related CO₂ emissions.

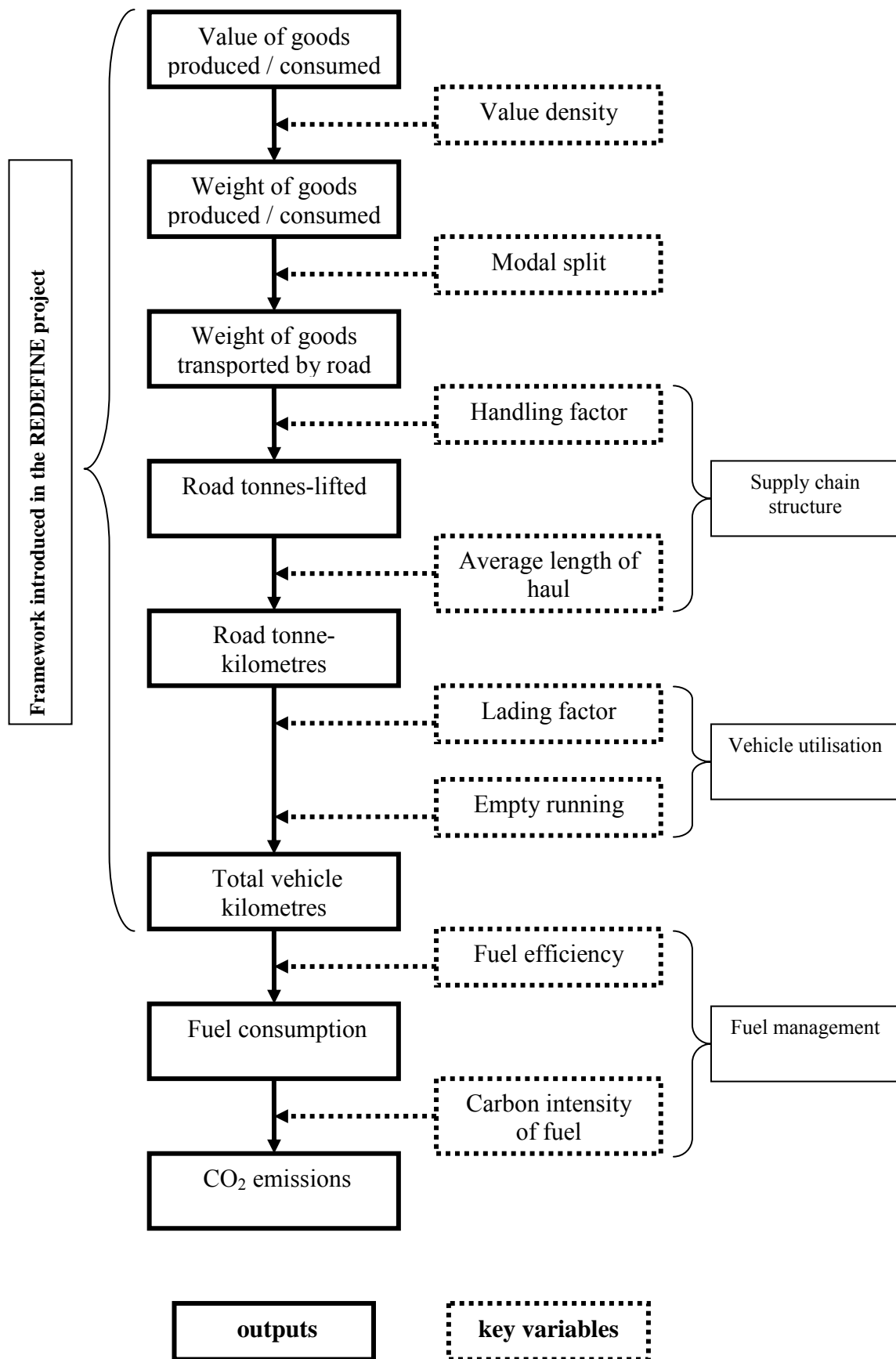


Figure 3.6. Framework linking economic activity, road freight traffic and CO₂ emissions
Adapted from: REDEFINE, 1999, Cooper et al. 1998

Based on a review of the literature presented above it was decided to use the framework shown in Figure 3.6 as a theoretical model of the complex inter-dependencies between a number of logistics outputs and variables. This framework is largely based on the one applied in the REDEFINE project (upper part of the figure). In the bottom part, it draws on the idea presented initially by Cooper et al. (1998) to link the demand for road freight transport to environmental impacts associated with that demand. However, instead of factors such as fuel consumption, engine technology and vehicle mix, two variables, i.e. fuel efficiency and carbon intensity of fuel are introduced.

The key variables in the framework can be defined as follows (REDEFINE, 1999, Department for Transport, 2009a):

- **Value density** – this is a ratio used to convert the value data on economic output / consumption into a weight based measure. It is expressed as value per a weight unit of a product (e.g. £/tonne).
- **Modal split** – represents the division of the tonnes or tonne-kms transported by the different modes of transport. E.g. road's share is expressed as the tonnes / tonne-kms moved by road against the total tonnes moved / total tonne-kms.
- **Handling factor** – indicates the number of links in a supply chain. It can be estimated by dividing tonnes lifted by the total weight of goods moved. As tonnes lifted are recorded every time goods are loaded onto a vehicle, the same load gets recorded several times as it makes its way through the supply chain. Thus, dividing tonnes lifted by the actual weight of loads moved gives a crude estimate of how many times, on average, goods are being handled as they move along the supply chains, i.e. number of links in the chain.
- **Average length of haul** – the average distance each unit of freight is moved on a single journey. It is estimated by dividing tonne-kms by tonnes lifted.
- **Lading factor** – the ratio of what a HGV actually carried to the maximum that it could have carried if, whenever loaded, it was loaded to its maximum carrying capacity.
- **Empty running** – the proportion of total vehicle kms run without a load.
- **Fuel efficiency** – expressed as distance travelled per a unit of fuel used (e.g. mpg).
- **Carbon intensity of fuel** – the amount of CO₂ emitted per unit of fuel used.

Further, handling factor and the average length of haul determine the supply chain structure. Lading factor and empty running are the two parameters of vehicle utilisation and fuel efficiency and carbon intensity of fuel can be subsumed under the heading ‘fuel management’. This framework can be used to estimate how changes in each of the variables can, *ceteris paribus*, contribute to an increase or a reduction in the CO₂ emissions from road freight transport. This makes it particularly useful for this research project as it approaches the problem of minimising CO₂ emissions from a logistics industry perspective.

3.5. Review of Key Variables

In this section, the key variables influencing the relationship between the economic growth and CO₂ emissions from road freight transport sector are reviewed.

3.5.1. Value density

As mentioned above, the value density expresses the value in fixed prices of a tonne of a commodity. It transforms economic quantities of production into a physical mass of goods (Fosgerau and Kveiborg, 2004). However, obtaining value densities for different commodity groups is not a straightforward exercise. Fosgerau and Kveiborg (2004) were able to calculate value densities directly from Danish national accounts data. This data covers the period from 1981 and 1992 detailing production by industry and commodity both in fixed prices and in tonnes. The estimated value densities decreased between 1981 and 1983 and remained relatively constant over the rest of the period. Leonardi et al. (2006) were able to obtain production data in terms of value and weight from German statistics for the period from 1995 and 2002. The value density calculated for the German economy exhibited a modest reduction over that time.

Unfortunately, very few countries (e.g. Denmark and Germany) have comprehensive data that permit the calculation of value density. Researchers in other countries have to rely on trade data, i.e. exports and imports to approximate value densities. Limited availability of weight of output data is one of the greatest problems in estimating value densities in the UK. For many sectors of the economy such data does not exist. In the past, there were attempts to use trade data to calculate average value density figures for some of the commodity groups. For example in the REDEFINE project import and export data on value and weight of commodities traded was used to estimate value densities for a number of product categories. An assumption had then to be made that

goods produced domestically would have the same value densities. However, all such approximations are unavoidably subject to a large margin of error. Based on the Danish data, Fosgerau and Kveiborg (2004) found that substituting production data with import or export data resulted in a significant decrease in the reliability of their model with the predicted transport volumes between 70 and 80% of the observed transport volumes. Thus, estimation of value density tends to be considered as one of the weakest links in freight transport modelling (Kveiborg and Fosgerau, 2004).

On a macro-level, value density can be expressed as the ratio of GDP to Direct Material Consumption (DMC) (i.e. domestic extraction of materials + imports – exports). In the UK, this ratio has been increasing for the last two decades (Piecyk and McKinnon, 2009a). At the European scale, Tight et al. (2004) report that, based on a survey of 100 experts, increasing value density of products is believed to have reduced transport volumes across Europe. However, this has been outweighed by other changes in the freight transport sector such as increases in handling factor and / or average length of haul. On a micro (product) -level, however, increasing value density is considered as a “key determinant of the level of centralisation” (p.144) with higher value density goods being manufactured and stored at a few large-scale locations. This may increase the distances over which goods are being transported to their final destinations (Lovell et al., 2005).

The inverse of the value density ratio (i.e. material inputs to the value of economic output) is called material intensity. According to Schleicher-Tappeser et al. (1998) the main factors contributing to a decrease of material intensity and, thus, to an increase in value density are:

- Structural change of the economy towards the service sector.
- Increased use of lighter materials.
- Miniaturisation of products.
- Increasing importance of design and quality aspects.

As argued above, value density / material intensity have a great impact on freight transport growth. Thus, if significant reductions could be achieved in the overall material requirements of the economy, this would translate into a related decrease in demand for freight transport activity (Pastowski, 1997). Present evidence suggests that there has been a decline in the material intensity of industrial economies between 1970s

and 1990s (Adriaanse et al., 1997, Matthews et al., 2000). However, this did not substantially reduce the overall freight transport intensity because the average length of haul increased during the same period (Pastowski, 1997). Rodriguez Casal et al. (2005) calculated that, in the EU, a large reduction of material intensity, i.e. substituting material goods with virtual equivalents and a shift from products to services, could cut the predicted growth in freight movements in 2020 by 20%. With less material input required to achieve a certain level of economic output, the overall demand for freight transport should be in decline. However, as goods are becoming more valuable, transport's share of the final selling price decreases, altering the economic trade-offs between transport and other commercial variables (McKinnon, 2007a). This may give companies more incentive to for example centralise production and distribution, leading to the rebound effect, where the total transport volumes increase as a result of goods being carried over longer distances (Cleveland and Ruth, 1999).

3.5.2. Modal split

Road is by far the dominant mode for goods movement in Great Britain. Road freight transport was responsible for 82% of goods lifted and 65% of tonne-kms moved in 2008, compared with 5% / 9% by rail, 6% / 21% by water and 7% / 4% by pipeline (Department for Transport, 2009a,b).

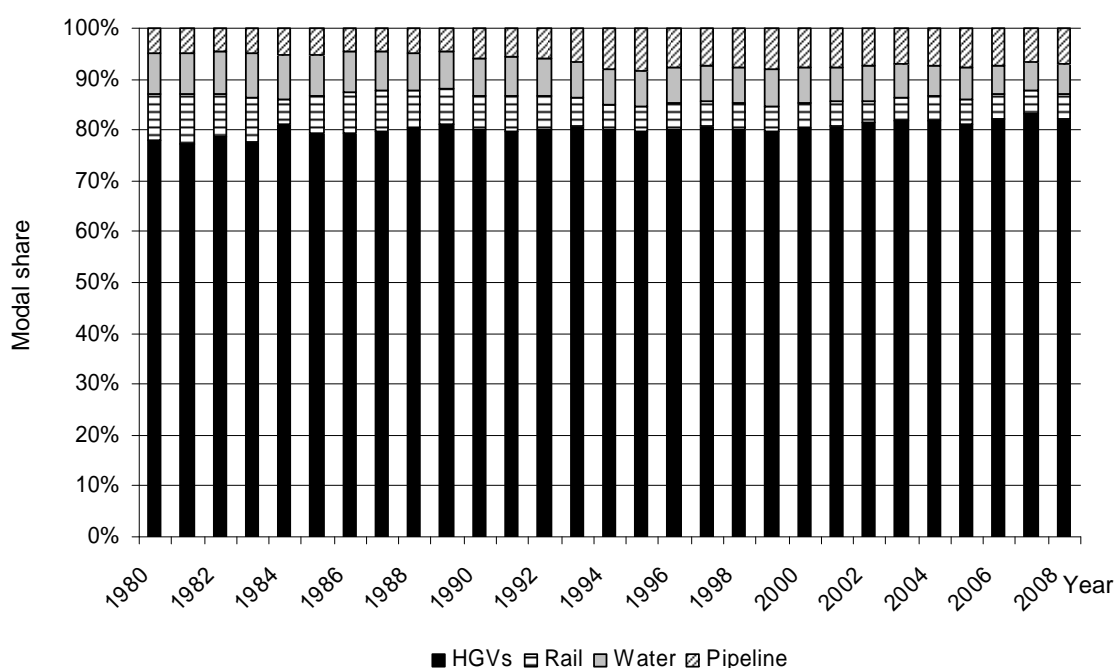


Figure 3.7. Freight modal split by tonnes lifted.
Source: Department for Transport, 2009a,b

The share of tonnes lifted by HGVs increased from 78% in 1980 to 81% in 1984 and, since then, it has been relatively stable at around 80-82%. Overall, the tonnes lifted by lorries grew from 1317 million tonnes in 1980 to 1724 million tonnes in 2008, an increase of 31%. In terms of tonne-kms moved, trucks' share of the UK freight market had been increasing up to 1997 and then declined by 4% between 1997 and 2005. McKinnon (2009a) suggests that this break in the earlier trend can be partly associated with the privatisation of rail freight services in 1996. Nevertheless, road's share increased again to 65% in 2008. McKinnon (2007b) attributes this increase to the reduction in coastal shipping tonne-kms, due to the decline in the North Sea oil production. In total, over the period between 1980 and 2008, tonne-kms moved grew by 69% from 90 to 152 billion tonne-kms.

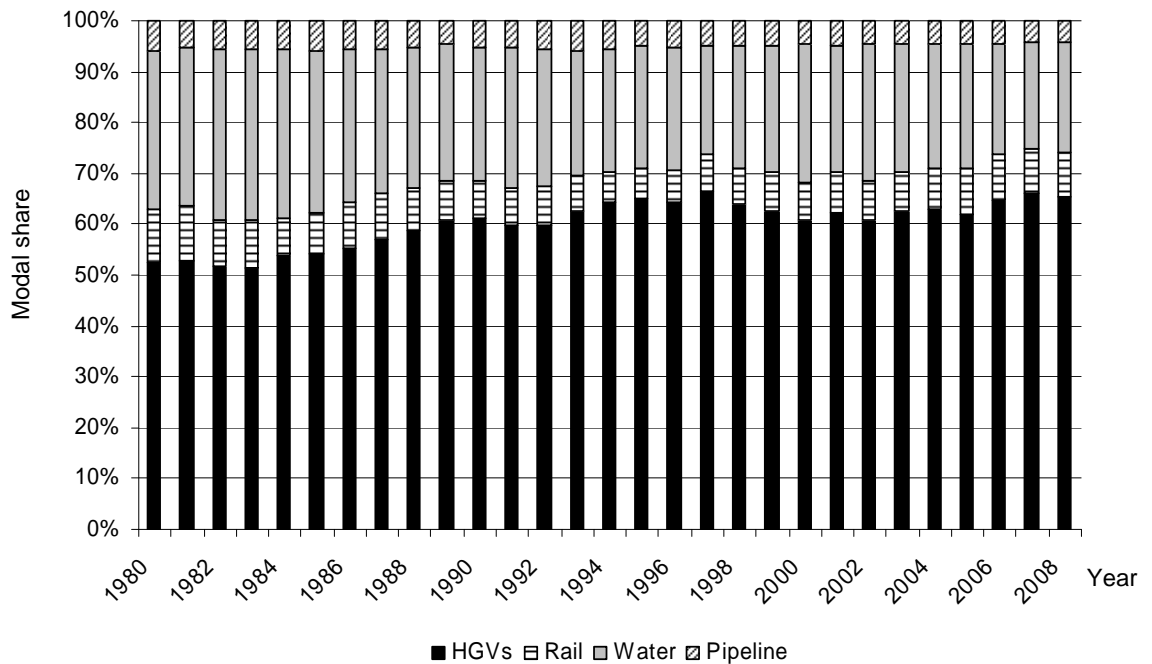


Figure 3.8. Freight modal split by tonne-kms carried.
Source: Department for Transport, 2009a,b

Given that, after airfreight, road is the most CO₂ intensive transport mode (McKinnon, 2007b), shifting freight to rail, waterborne or pipeline transport leads to a reduction in the absolute level of energy consumption and CO₂ emissions from moving freight (Vanek and Morlok, 2000). Significant modal shift can be achieved not only by promoting alternative modes, but also by increasing the share of intermodal services. Intermodal transport can be defined as the movement of goods in one loading unit (e.g. a container) or vehicle by successive modes of transport without handling of the goods while changing modes (Bontekoning et al., 2004, Woodburn, 2008). The volume of

intermodal transport represents around 5% of total freight in Europe (Savy, 2009). Although an equivalent figure for the UK is not known, intermodal freight transport is developing into a significant sector of the freight transport industry and helps to improve the environmental performance of freight transport sector as a whole.

Although there is a large body of literature on the theoretical aspects of mode choice, typically utilising operational research and mathematical modelling, as well as emphasising the environmental and social benefits of modal shift, there has been very little attention given to the importance of mode selection in logistics and supply chain decision-making (Woodburn, 2003). Further, it is argued that freight transport by alternative modes is only competitive when the distance travelled is relatively long and shippers can accept transit times that are longer and less reliable than by road (Vanek and Morlok, 2000). According to Van Klink and Van den Berg (1998), intermodal transport can compete with road haulage only if large volumes are moved over relatively long distances. For Europe, they quote a minimum distance of 500 kms. Moreover, the analysis of Belgian data by Beuthe et al. (2001) indicates that road transport demand in terms of tonnage is inelastic⁵ while it is elastic when measured in tonne-kms. This confirms the dominant position of road haulage over the short distances as changes in the price are more likely impact on the distance travelled rather than on tonnage moved. Both tonnages and tonne-kms moved by rail and inland waterway are elastic, with higher elasticities for short distance movements. This is because of their relative high cost over short distances. Thus, small changes in the price are likely to result in disproportionately large changes in demand.

However, modal choice is not only affected by price, other factors are relevant too. Cunningham (1982) reviews freight modal choice analysis techniques and concludes that transport mode selection is a function of three factors. These factors are “the costs incurred by the competing modes of carriage, the shipper’s predispositions (which are influenced by his perceptions concerning carrier performance characteristics) toward the various competing modes and carriers, and the total transportation and non-transportation costs to the shipper” (p.74). A content analysis of 75 publications conducted by Cullinane and Toy (2000), showed that the five most often considered factors in the freight mode selection literature are cost, speed, transit time reliability, characteristics of the goods and service. Around a half of respondents interviewed by

⁵ Elasticity of demand measures the output effect i.e. change in demand as a result of a price change.

Woodburn (2003) said that improving rail service quality, increased taxes on road haulage, introduction of road pricing or decreasing the cost of using rail would provide an incentive to switch to more use of rail.

Similarly, Blauwens et al. (2006) analyse the effectiveness of different policy measures aimed at triggering a freight transport modal shift from a business logistics perspective. Using a hypothetical market for container transport between a seaport and its hinterland, they evaluate the likely effectiveness of three policy measures aimed at encouraging a modal shift in that market, both individually and in combination. The measures considered are: an increase in the costs of road transport (e.g. through road or congestion charging schemes), a decrease in the lead times of combined road/rail or road/barge transport by half a day and a decrease in the costs of rail transport (e.g. as a result of a deregulation of the rail freight transport market). For both an increase in the cost of road and a decrease in rail transport three scenarios of 5%, 10% and 20% change were assessed. On a standalone basis, increasing the cost of road transport by 20% had the greatest impact on reducing the share of this mode (a reduction by almost 14%). The positive changes in modal split were reinforced further when combinations of the three policy measures were considered. Also the research undertaken by Golias and Yannis (1998) suggest that, in order to promote alternative transport modes and/or combined transport, financial support for capital investment required is a priority measure, before improvements in freight rates, transit times and improved profitability. Further, modal choice decisions appear not to be related to the size of a company.

Finally, based on a recent literature review, Meixell and Norbis (2008) point out that concerns about environmental factors and energy use are still not sufficiently represented in the freight transport mode selection literature. They found that none of the 48 articles reviewed addresses the environmental or energy aspects of mode choice. Rondinelli and Berry (2000) conclude that as each transport mode has a range of environmental consequences, analysis and assessment of these should be an integral part of mode choice decision-making.

Rail

In the UK, the volumes of freight moved by rail had been in a long-term decline since the 1950s, with this trend continuing over the mid-1980s and 1990s “though with a shorter-term cyclical trend within the longer-term downward one” (Woodburn, 2001,

p.2). Tonne-kms moved by rail reached a low point of 13 billion tonne-kms in 1994 and 1995. More recently, the volumes have been increasing gradually to 21 billion tonne-kms in 2008, though the percentage share of rail in the freight transport market has been relatively stable at 8-9% over the last decade. As McKinnon (2009a) suggests, an increase in the volumes of freight moved by rail may be partly attributable to privatisation of railfreight services in 1996.

Conversely, the tonnes lifted by rail dropped from 122 million tonnes in 1992 to 103 million tonnes in 1993 and remained relatively stable since then. The reduction in the total tonnes lifted by rail while tonne-kms are still increasing suggests that the decline in tonnage has been offset by longer average length of haul. In fact, the average length of haul increased by nearly 73% from around 120 kms in the early 1990s to 207 kms in 2007. This increase has been largely caused by the changes in the supply structure of coal, with a large share of coal being now imported and, thus, being moved over longer distances from the points of entry to GB rather than from domestic points of extraction (Department for Transport, 2009d). Coal and coke accounted for 38% of tonne-kms moved and 46% of tonnes lifted by rail in 2008. Further, the share of coal in the tonnes lifted by rail has been relatively stable over the last ten years, while the share in tonne-kms increased by 12% between 1998 and 2008 (Department for Transport, 2009b). This confirms that the increasing distances over which coal is moved largely contribute to the overall increase in the average length of haul by rail.

According to Woodburn (2001), the long-term downward trend in rail freight volumes has been caused mainly by the structural change of the British economy, particularly the decline in heavy industry, resulting in a contraction of the bulk freight market. The increased competition from road haulage and realignment of national industry away from rail towards road network, have also been major factors. Further, the potential for increasing rail's share of the freight transport market has been identified. For instance, research by Woodburn (2003) showed that out of 39 companies representing different industry sectors, 11 were using rail, 20 could envisage the possibility of using it in next five years and only 8 saw no potential for use at all. Moreover, across the whole sample, on average 19% of each company's traffic was potentially viable for rail, though with a standard deviation of 19%. Woodburn (2003) concludes that these figures reveal a large potential market for rail. However, variations in opportunities for using rail between individual companies were significant.

Woodburn (2006) highlights the importance of the non-bulk sector in the future growth of rail freight. He discusses the recent trends in the intermodal and less-than-trainload (LTL) services in Britain, concluding that the former are currently better placed to capture premium logistics traffic. Operational problems in the LTL sector (such as for example the lack of information about delayed arrivals and the impacts that such delays have on rolling stock availability or infrequent trip workings, etc.) are still of great significance and numerous gaps in service provision would need to be filled in order to increase its share of the freight market. Further, the potential for rail to capture more of the container freight traffic in Britain is discussed in Woodburn (2007a, 2008). Also Haywood (1999) says that “the intention is that the growth will come from both reclaiming traditional bulk traffic previously lost to road, but also by winning new traffic, including wagonload, intermodal and time-sensitive business” (p.267). In all cases, the opportunities for rail to increase its share are identified, but they are critically dependent upon improvements in the service levels offered and enhancements to the capacity and capability of the network.

After analysing productivity and efficiency of the rail freight sector in Europe, Hilmola (2007) concludes that significant restructuring of the sector would be required to ensure its future prosperity. The identified restructuring measures involve increased internalisation of external costs, mergers and acquisitions after the sector was opened to free competition in 2007, as well as intermodal transport solutions. Financial support from governments is also an important measure of promoting shift to alternative transport modes. Woodburn (2007b) reviews the rail freight grant funding system in Britain, and concludes that Freight Facilities Grant (FFG) awards have been largely successful. FFGs are available to potential or existing customers to contribute towards the costs of assets needed to retain or attract freight onto the rail network, where it can be demonstrated that there is an environmental benefit. During over 30 years of their existence, FFGs have attracted significant private sector investment and helped to promote rail freight transport.

New technologies and innovative logistics solutions could also help to increase rail's share of the freight transport market. Trip and Bontekoning (2002) investigate the potential for integrating small freight flows, particularly from peripheral regions, to generate sufficient volumes for intermodal transport, which can potentially promote the modal shift from road to rail. Based on a case study of a terminal in Valburg (the

Netherlands), they admit that although in theory such an initiative seems possible, a number of practical problems may occur, reducing the expected positive impact on modal shift. Jeong et al. (2007) model a theoretical hub-and-spoke railfreight network across 10 European countries and identifies a number of cost effective scenarios. However, they also highlight a number of likely implementation problems, concerning, for example, the sequencing of investment in potential hubs, sources of funding, uncertainty as to future European policy on rail transport, etc. Ohnell and Woxenius (2003) predict that intermodal transport will become more popular within Europe, resulting in more extensive networks of express freight services. They argue that there are clear technical, logistical and economical opportunities for rail to offer services on a “faster than road but cheaper than air” basis (p.736) and the attractiveness of express rail freight transport is high, especially when an air link can be substituted.

Waterborne transport

Less attention is given in the literature to waterborne freight transport, even though it carries the greater proportion of domestic freight than rail, both in terms of tonnes lifted as well as tonne-kms moved. Domestic waterborne freight transport consists of inland waterway, coastal shipping and one-port traffic to and from offshore installations and sea dredging (Department for Transport, 2009e). Inland waterway involves moving freight on canals, river and estuarine waterways. Coastal shipping involves “vessels operating between two or more points of the UK, in contrast to short sea shipping, which refers to vessels travelling between the UK and the mainland Continent of Europe or the Republic of Ireland” (Saldanha and Gray, 2002, p.77).

In 2008, 123 million tonnes were lifted and 50 billion tonne-kms were moved by waterborne transport. Looking at the longer term trend, tonnes lifted peaked at 156 million tonnes in 1988 and have been declining gradually since then. Tonne-kms have been relatively stable since early 1980s, with two peaks at 67 billion tonne-kms in 2000 and 2002. Crude petroleum and petroleum products are the main cargo moved by waterborne transport, accounting for 73% of its total tonne-kms and 47% of tonnes lifted (Department for Transport, 2009e). Further, waterborne transport is the third most efficient mode in terms of CO₂ emissions per tonne-km moved in the UK, just after pipeline and rail (McKinnon, 2007b).

Despite the historically well-developed canal system in Britain, water freight seemed to be neglected in the national transport systems in the second half of the 20th century and canals represent only a small proportion of total waterborne tonne-kms. Since late 1990s, however, the economic and environmental advantages of waterborne freight have been clearly recognised leading to a more positive approach towards this mode (Hilling, 2003). The new initiatives involved e.g. the Waterborne Freight Grants (WFG) given in the form of short-term operating assistance to enable establishing new coastal and short sea shipping services where environmental benefits can be identified (Dougherty, 2004).

Paixao and Marlow (2002) review the strengths and weaknesses of short sea shipping. Given their very similar nature, the same benefits and problems apply to coastal shipping and inland waterway transport. Lower freight rates, virtually unlimited capacity of the sea, relatively low costs of investment and maintenance of port infrastructure, compared with the one required by road and rail, environmental sustainability and good safety records are listed amongst the advantages of waterborne transport. Inability to provide door-to-door service, need for additional handling, lack of flexibility, bureaucracy, long transit times are the major drawbacks of this mode.

According to Rohacs and Simongati (2007), although inland navigation is considered a safe, relatively cheap, environmentally friendly and effective mode, it is also slow, inflexible and usually requires feeder movements at both ends. Additional handling and administration involved may also reduce the cost advantage inland waterway transport. Excessively long transport time and incongruity of cargo volumes between larger ships and smaller consignments are listed as major obstacles in Saldanha and Gray (2002). Thus, only high-speed ferries could compete effectively with road freight transport and meet the demand of shippers for rapid transit time, though their higher operating costs reduce their price competitiveness. Also time spent in ports needs to be reduced to improve the overall performance of waterborne transport.

Baird (1997) discusses a potential sea freight transport system and coastal Ro-Ro ferries between Scotland and England. Similarly to Saldanha and Grey (2002), he concludes that such a system would only be viable, if high-speed ferries were used to compete with current road transport transit times. However, if high-speed ferries were used, they would be unable to offer any price advantage over the UK road haulage rates. This leads

to a conclusion that “the technology and operations of shortsea shipping will need to be fundamentally changed before any meaningful modal shift from road to sea can take place” (p.112). Consequently, Baird (2007) calls for more public sector investment in waterborne transport, arguing that “the seaway-equivalent infrastructure of roadways and railways is the deck of a ship” and “there continues to be a mismatch whereby transport policy throughout Europe accepts the continued state financing of roadway and railway infrastructure but not seaway infrastructure” (p.287). If this approach was accepted and adequate policy measures introduced, this would help to overcome market distortions and attract more of higher value traffic, improving the attractiveness and competitiveness of waterborne transport.

Although waterborne transport is generally perceived as the slowest mode, Groothedde et al. (2005) discuss intermodal transport network combining road and inland waterway for the movement of fast-moving consumer goods. They describe a case study in which the aim was to design of a hub network using barges for the transport of palletised fast moving consumer goods. A number of companies were involved in the case study, collaborating in order to achieve sufficient economies of scale and increased level of reliability of inland waterway transport. Examples like this suggest that logistical collaboration between companies could lead to a greater use of alternative modes of transport, allowing organisations to benefit from reduced freight rates and leading to better overall environmental performance of the transport sector. Also facilitating such logistics solutions can become a new market opportunity for logistics service providers, if more of similar initiatives prove successful. It is also worth noting that, due to a similar nature of products carried, waterborne modes often compete with rail over the available traffic. Emergence of logistics service providers specialising in facilitating the use of alternative modes could help both waterborne transport and rail to compete effectively with road, instead of with each other, and gain an overall greater freight transport market share.

Pipeline

The pipeline transport statistics published by the Department for Transport are for oil pipelines only. There were 147 million tonnes of oil ‘lifted’ by the pipeline network leading to 10 billion tonne-kms moved that year. Tonnes lifted increased by 21% from 121 million tonnes in 1990 to 147 million tonnes in 2008, while tonne-kms remained virtually stable. The data is not comparable with earlier years due to changes in

coverage of statistics in 1990 (Department for Transport, 2009b). The one-fifth increase in tonnes lifted combined with a stable tonne-kms trend suggest a decline in the average length of haul over the period, i.e. more oil being moved over short distances. According to data presented by (Department for Transport, 2009d), the average length of haul by pipeline was 70 kms in 2008, compared to 123 kms in 1980. Further, most of this decrease occurred between 1986 and 1995, but the reasons behind this decline are not explained. Also, as only 12% of movements of crude petroleum and petroleum products are by road (Department for Transport, 2009b), the possibilities of influencing the overall modal split figures by shifting more oil into the pipeline network are somewhat limited.

3.5.3. Supply chain structure

Supply chain structure is characterised by two variables: the number of links in the supply chain and the average distance between them.

Handling factor

As discussed above, the number of links in the supply chain can be measured by the handling factor. McKinnon (1989) defines handling factor as the ratio of the tonnes lifted statistic to the weight of products consumed or exported. In other words, handling factor measures the frequency of lifts of the tonnes moved along the supply chain (Cool, 1997).

Handling factor is relatively difficult to estimate mostly because of different commodity classification systems used by different surveys employed to gather economic output and freight transport data. Also production / consumption data is typically reported in 'value' rather than 'volume/weight' units. Hence, it needs to be converted to volume / weight but, as discussed above, there is a lack of reliable conversion ratios. As can be seen, the handling factor is affected by similar issues as the value density ratio, i.e. the weight of output data is needed to derive both ratios. Also, as goods are processed along the supply chain they are reclassified and it is very difficult to relate freight data to changes in industrial structure from raw material source to final point of sale. Additionally, goods are likely to change weight in the production process and these changes will distort the handling factor (McKinnon and Woodburn, 1996).

Despite these problems, several attempts to calculate handling factor are recorded in the literature. According to McKinnon (1989), in 1980 the handling factor for food products in the UK was approximately five, i.e. there were on average roughly five links from raw material source to a retail outlet. This result can be taken with a great degree of confidence, as detailed data on food production / consumption was used to obtain this estimate.

In the REDEFINE (1999) project handling factor for the road freight transport in the UK, across of sectors, was reported to have increased by 18% between 1985 and 1995 (from 1.82 to 2.14). The handling factors were quite low and suggested that on average goods were handled only twice before they reached final consumer. Also, the results may be distorted by the lack of weight of output data in many sectors of the economy and the need to estimate it using trade data. For the food and drink sector, the handling factor dropped from 4.1 in 1982 to 3.6 in 1985 and then increased to 4.4. in 1995, which suggests a slightly lower number of handling points in a typical food produce supply chain as compared to the situation in 1980. A more recent attempt to estimate handling factors for the UK have failed due to unavailability of the data on the weight of goods produced / consumed or suitable value-to-weight conversion ratios to derive reliable estimates (Sorrell et al., 2009).

Kveiborg and Fosgerau (2007) report a declining handling factor for road freight transport in Denmark between 1981 and 1997 (-1.05% per annum), but do not present any absolute values. They were able to obtain the weight of production data directly from Danish national accounts. Their research shows that the decline in handling factor contributed to a reduction in both road tonne-kms and vehicle kms growth rates over that period. The authors argue that when average unit of road freight makes fewer journeys, this leads to fewer kms and reduced road freight transport volumes. As the average distances travelled increased over the same period, the net effect was still an increase in both vehicle kms and tonne-kms. Conversely, Leonardi et al. (2006) report an increasing handling factor for road freight traffic in Germany between 1995 and 2002 (0.22% per annum). Unfortunately, they do not present any absolute values either.

Kveiborg and Fosgerau (2007) also note that data used to calculate the handling factor may be influenced by the two following factors:

- Packaging- the production data records the weight of products without packaging while freight data includes packaging. Also, the amount and weight of packaging may change over the years.
- As freight statistics record only domestic movements by road (i.e. exclude starting or ending abroad or cabotage trips by foreign operators or transport by alternative modes), if more goods are exported directly from a production site or travel on other modes than road, this may distort the handling factor.

Trends in handling factor

As can be seen, very limited data are available on the weight of goods produced and consumed (McKinnon, 2003). Thus for the purpose of this thesis a slightly modified approach was applied. Instead of trying to find proxies for the unavailable data, which had previously proven highly problematic (Sorrell et al., 2009), an approximate handling factor was calculated by dividing the tonnes-lifted estimate for 2007 by corresponding material flow value published in the UK National Accounts (Department for Transport, 2009a,b, Office for National Statistics, 2009b).

The Direct Material Input (DMI) was used as a substitute for the weight of output data. DMI is defined as “the sum of the total amounts of primary resources extracted from the UK environment and the amount of imports into the UK” (Office for National Statistics, 2009b, p.34). DMI includes the weight of goods exported and excludes the excess material or hidden flows associated with the domestic extraction and import of materials. The DMI plus the indirect flows is called Total Material Requirement (TMR). However, the total material consumption is not fully compatible with the weight of goods transported. Not all materials will be moved in a way that fits the definition of freight transport, i.e. some may be moved internally on extraction sites (e.g. overburden in mining) (Pastowski, 1997). Thus, DMI was considered to be the most appropriate estimate of the weight of goods within an economy. The DMI has been relatively stable over the last four decades, with only a modest 7% increase from 801 million tonnes in 1970 to 856 million tonnes in 2007.

In order to estimate the weight of goods moved by different transport modes, the proportions of tonne-kms moved by different modes were used. The estimated handling factors for all modes and road freight transport are shown in Figure 3.9.

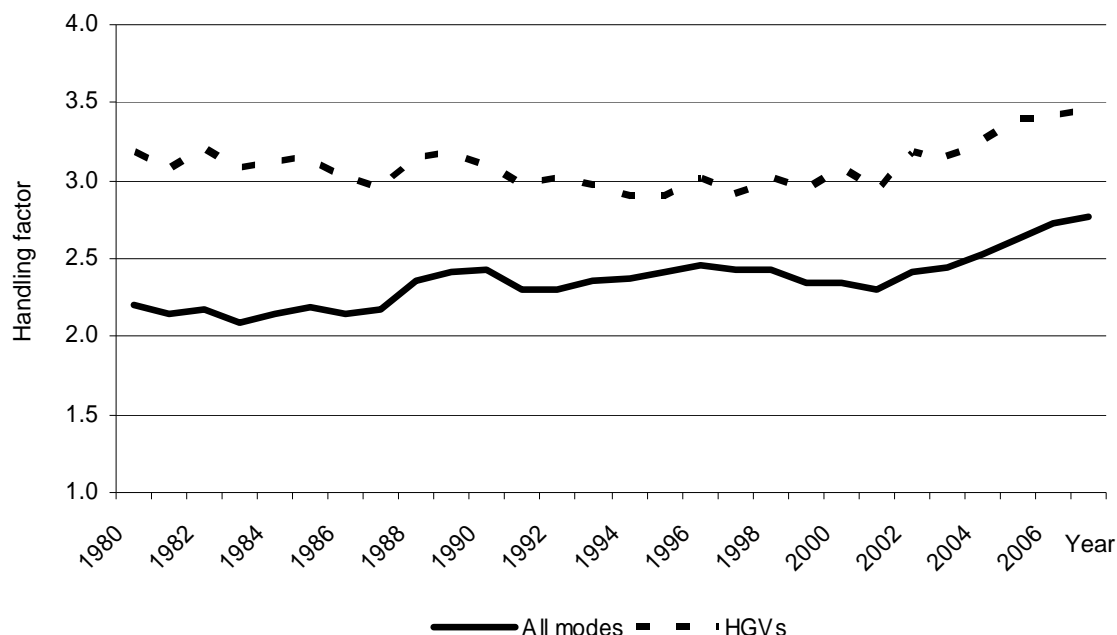


Figure 3.9. Handling factors for road and all modes
Sources: Department for Transport, 2009a,b, Office for National Statistics, 2009b

The handling factors for all modes of transport increased gradually from 2.2 in 1980 to 2.5 in 2007. The handling factor for goods moved by road had first decreased from 3.2 in 1980 to around 2.9 in the mid-1990s and then the trend has reversed, reaching the value of 3.5 in 2007. This suggests that supply chains served by road were subject to restructuring pressures towards reduction of links in the supply chain up to mid-1990s, and more recently structures with more handling points started to emerge.

Factors influencing handling factor

According to McKinnon (2008), handling factor has been a subject to contradicting business trends. The handling factor has been decreasing as a result of:

1. **Disintermediation** – where one or more levels in the supply chain are bypassed and goods are distributed more directly to customers.
2. **Vertical integration** – where inter-related processes, e.g. processing and storage, are consolidated on the same site

Conversely, the following developments are likely to result in more links within supply chains:

1. **Globalisation** – wider sourcing of supplies, especially from overseas, generally adds extra links to ‘end-to-end’ supply chains. This does not necessarily change the ‘domestic’ handling factor but is very likely to result in increased handling factor on a global scale. This is similar to the impact of offshoring on the decoupling of GDP and freight transport as discussed in Section 3.3.3. Offshoring of manufacturing is likely to reduce the overall amount of domestic freight transport / handling factor but, at the same time, increase these two variables on a global scale.
2. **Vertical disintegration of production** – occurs when some intermediate activities are outsourced to subcontractors, resulting in products moving between a greater number of facilities in the production process.
3. **Insertion of additional stages in the production process** – for example changes in consumption habits such as shift to more pre-prepared or ready-made food, can require insertion of more processing points into the food supply chain.
4. **Changes in product mix** – as economies develop, consumers switch greater proportion of their expenditure away from basic commodities towards more complex products, for instance electronic equipment, requiring multi-stage assembly operations.
5. **Growth of online retailing** – this adds an extra link as a supply chain now ends at the customer’s home rather than at the shop.
6. **Development of primary consolidation and centralised sortation** – in order to improve / maintain vehicle fill during a period of tightening JIT pressures, companies are channelling more consignments through consolidation centres where their products are combined with those of other suppliers for delivery in a fully loaded vehicle. Also, the development of hub-and-spoke networks for handling parcel and pallet loads has added to the average number of links in the supply chains.
7. **Reverse logistics** – with more waste being recycled or reused instead of being sent to landfill, new reverse channels comprise more nodes and links for sorting and reprocessing.
8. **Modal shift and greater use of intermodal services** – switching freight to alternative modes very often requires extra road feeder movements to and from terminals.

The relative contributions of the factors listed above are virtually impossible to quantify as their strength varies across industry sectors, commodity groups, countries and even regions (McKinnon, 2008). However, looking at Figure 3.9 it is evident that in GB the trends increasing the handling factor have been prevalent since early-2000s.

Average length of haul

The average length of haul had increased significantly over the 20th century from just 35 kms in 1953 to 95 kms in 1999. Since then it has declined slightly, stabilising at 86-87 kms in the last five years, still well above its 1980 level. Moreover, articulated lorries have significantly longer average length of haul than rigid vehicles. Also, the pattern in average length of haul is slightly different for the two categories of trucks. The trend for articulated vehicles exhibits a steeper increase until the late 1990s and a falling average length of haul since then. Rigid vehicles show a relatively stable pattern over the last three decades with a slight peak around early 2000s.

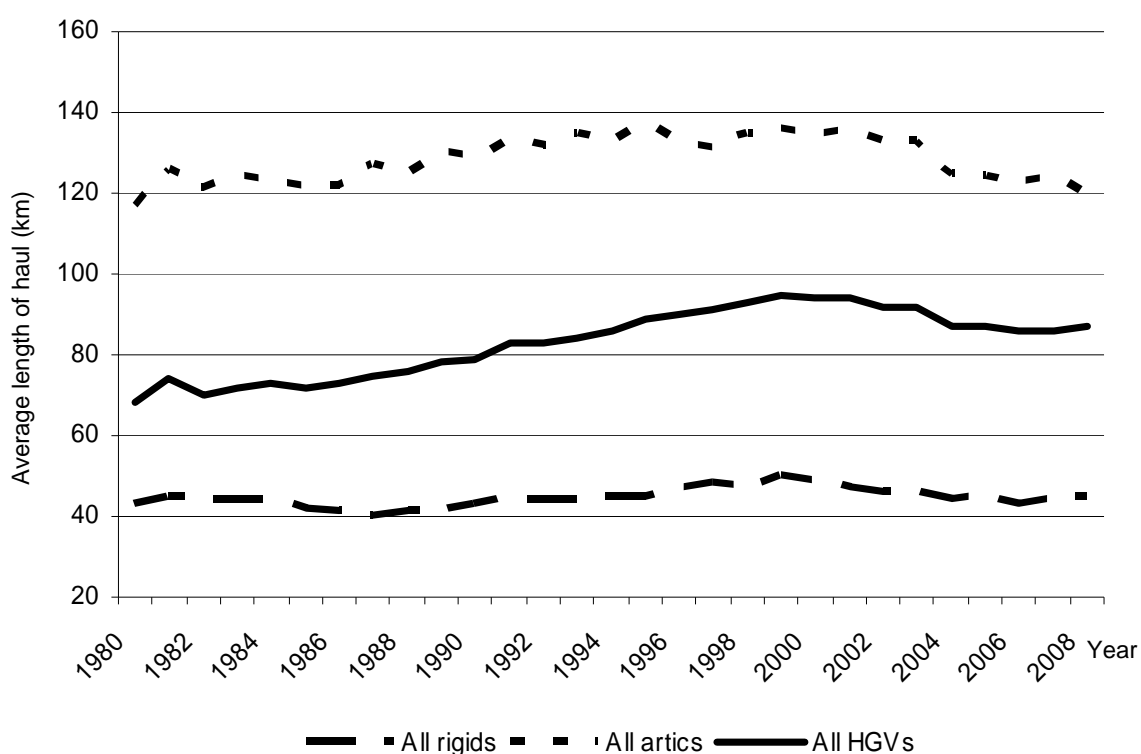


Figure 3.10. Average length of haul
Source: Department for Transport, 2009a

Factors influencing average length of haul

One of the most frequently mentioned reasons offered for the lengthening of the average length of haul is centralisation of economic activity. Spatial concentration of economic activity enables companies to exploit economies of scale in operations but results in greater distances between factories, warehouses and other facilities within the logistics system (McKinnon, 1998b). Also, the concentration of international freight on main hub ports and airports results in expanding hinterlands and longer domestic feeder movements (McKinnon, 2008). According to McKinnon (1989), concentration of inventory was likely to have been a major cause of the over 50% increase in the average length of haul between the late 1960s and early 1980s. At the national scale, the centralisation of economic activity and related increase in the average length of haul is likely to have significantly contributed to the overall growth in freight transport volumes. The REDEFINE project confirmed that the 24% increase in the average length of haul was the main driver of road freight growth in the period reviewed in the study, i.e. between 1985 and 1995.

Wider sourcing of supplies and expansion of market areas is also believed to have increased the distances over which products travel. “As transport and communication networks have improved, companies have extended their ‘logistical reach’ to find better, cheaper and more diverse sources of supply and sell their products to more distant customers” (McKinnon, 2008, p.11). This trend may benefit the ultimate consumers, who are now provided with a wider choice of products. However, it may also put some regions at risk of losing significant parts of economic activity to other parts of the world offering lower operating cost and add to the global environmental problems through increased transport activities. Also, in the case of outbound distribution, the longer average distances to the final customer increase the response time and may negatively influence the required level of customer service (Chopra, 2003).

At a company level, everyday routing decisions can significantly impact on the distance travelled, for example a vehicle may be routed circuitously to avoid congestion. Also the methods used to plan the routes can influence the length of a journey (McKinnon, 2008). Computerised vehicle routing and scheduling systems (CVRS) can help companies to reduce mileage necessary to meet a given workload. In a recent survey of CVRS users, 29% of companies reported reduced mileage as one of the benefits from implementing such a system (Freight Best Practice, 2007a,b). McKinnon

(2003) quotes estimates of an average reduction of the distance travelled as a result of CVRS implementation as 5 – 10%.

The supply chain structure considerably affects the overall performance of logistics, particularly since there is a close correlation between the distance travelled and probability of empty running. Cundill and Hull (1979) established that the percentage of empty running declines as the length of a trip increases, reflecting the greater economic incentive to carry a load over longer distances. They indicate that for hauls up to about 300 km, the empty running declines steadily at a rate of a little under 1% per 10 km. Also, only about 15% of all trips over 500 km are empty, well below the overall average of 28%. On the other hand, there is also a strong relationship between distances travelled and maximum and minimum trip times, i.e. the longer the journey the more variable the travel times, which may result in limited opportunities to carry a backload on the return journey. Hence, as the average length of haul increases, more adaptation measures may be required to adjust the logistics system to less reliable transit times (McKinnon et al., 2008a, 2009). This may also impact on vehicle utilisation and the overall environmental performance of a company's transport division. The utilisation of road freight vehicles is discussed in detail in the next section.

Also, in a wider perspective, across all modes, changes in the average length of haul may also influence modal split as the share of road transport tends to increase for the shortest lengths of haul (Vanek and Morlok, 2000).

The trends in the handling factor and the average length of haul are mainly a result of wider economic trends and business processes. Thus, their contribution to a company's demand for road freight transport and resulting CO₂ emissions have tended to be a minor factor in strategic logistical decision making. Although still important, they may easily be offset by other arguments such as economics of scale from centralised production or warehousing. However, as environmental concerns are becoming increasingly important in corporate decision making, in future attempts to redesign logistics structures more emphasis will hopefully be put on optimising goods handling and distances travelled.

3.5.4. Vehicle utilisation

The level of vehicle utilisation is measured by key variables: empty running and lading factor.

Empty running

“A fundamental difference between passenger and freight transport is that people generally return to their starting point, whereas almost all freight consignments move in one direction, from point of production to point of consumption” (McKinnon and Ge, 2006, p.391). Thus, empty running is inherent in any freight transport system as empty vehicles need to be repositioned to the point where the next demand arises (Crainic, 2000). Although partly unavoidable, empty running contributes to road congestion, increases cost to road haulage operators and results in a range of negative environmental impacts (Gorick, 2006, McKinnon and Ge, 2006, Davis, 2008). Consequently, the reduction of empty running should be a priority in every sustainable transport system (DETR, 1999).

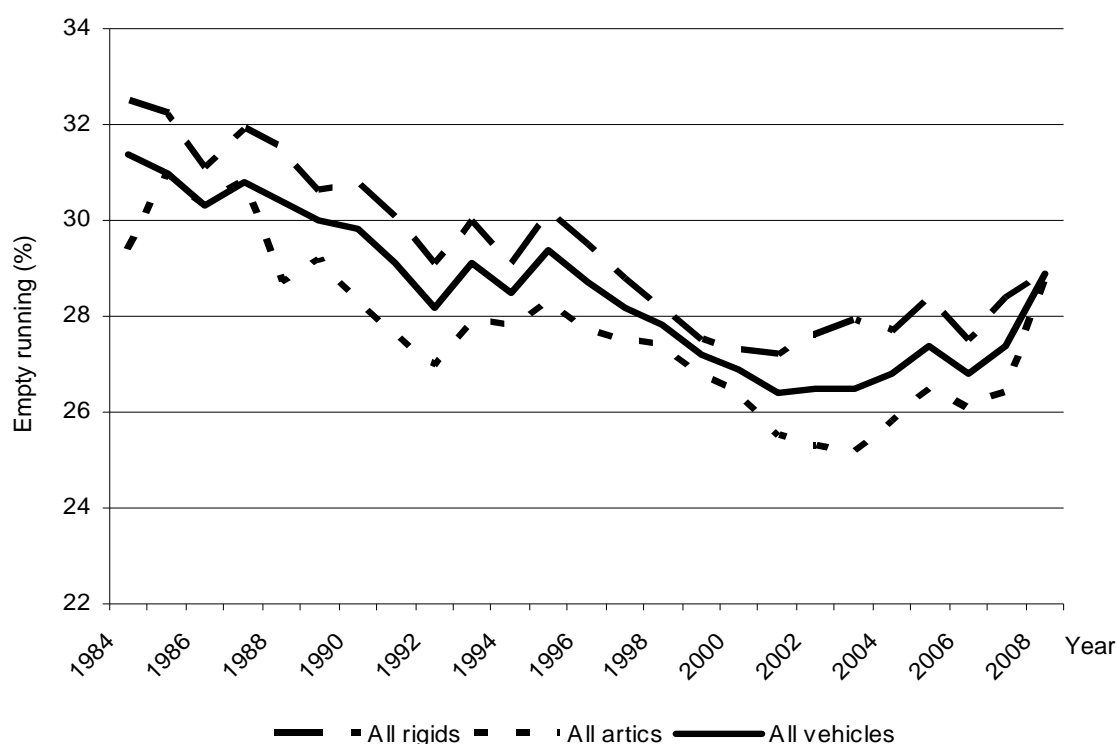


Figure 3.11. Empty running
Source: Department for Transport, 2009a

In the UK, empty running decreased from over 31% of the total distance travelled in the mid 1980s to 21% in 2001. However, since then it has risen again, reaching 29% in

2008. As a result, around 6140 million kms were driven unladen that year. The empty running by rigid vehicles had been persistently a few percentage points higher than by articulated vehicles until 2008, when the two values merged at 29%. Empty running appears also to be declining in most of the European countries for which data is available. Analysis by Piecyk and McKinnon (2009a) shows that the average level of empty running across 18 European countries dropped from 27.6% in 2004 to 27.1% in 2007. At the European level, in 2007 the UK was performing much better than countries like Cyprus, Ireland, Greece or the Netherlands. Denmark, Germany and Sweden were the most efficient across the sample.

Empty running varies not only between countries, but also across different sectors in the economy. Leonardi and Baumgartner (2004) found that 48% proportion of truck kilometres were run empty in the German container transportation business, compared to the overall average of 17% across 50 companies included in their sample. Similarly, McKinnon and Ge (2004) report an empty running mean value of 19% in the UK food supply chain in 2002, well below the national average. This figure then increased to 24% in 2007 and still remains lower than the UK mean value (Freight Best Practice, 2007c). In 2008, the highest levels of empty running were recorded in the energy and water supply, construction and agriculture, forestry and fishing sectors (42.8%, 42.5% and 37.7% respectively). Transport, storage and communication, health and social work and banking, finance and insurance sectors were the most efficient with only 23.6%, 24.1% and 25.4% kilometres run empty in 2008 (Department for Transport, 2009a).

Factors influencing empty running

McKinnon (1996) argues that the long-term decrease in the percentage of lorry kms run empty can be attributed to the following five factors:

1. **Increase in the average length of haul** – as discussed in the previous section, the economic incentive to find a suitable load increases with the distance over which a vehicle has to travel (for instance when it returns to base after a delivery to a customer).
2. **Change in trip structure** – the proportion of kilometres run empty declines as the number of drops per trip increases. This is because on a multi-stop journey only the last leg would normally be run empty and, at the same time, it is also likely to be relatively short.

3. **Greater use of load-matching services** – as load matching agencies provide an increasingly comprehensive range of services, including credit rating assessment of potential customer, the risk associated with picking up backload traffic on a spot hire basis is significantly reduced. This is likely to encourage more transport managers to try to find suitable backloads for their fleets. Using the UK as a case study, Davies et al. (2007) examine the extent to which information communication technology (ICT) and Internet freight exchanges affect the road freight transport industry. Their research shows that almost 33% of companies investigated used the Internet at least sometimes to access backloads and, out of them, 69% indicated that using freight exchanges had helped to reduce empty running.
4. **Reverse logistics**, i.e. growth in the reverse flow of packaging material and handling equipment
5. **Management initiatives to improve backloading**, e.g. collection of loads by suppliers, factory gate pricing, etc.

McKinnon and Ge (2006) updated the analysis of factors that might have contributed to a reduction of empty running. As a result, geographical imbalances in traffic flow and increasing cost of road transport were added to the list of factors affecting the empty running figure, with the former likely to have a negative impact. There is no explanation so far available why the percentage of kms travelled unladen has been increasing in recent years, most likely because of the uncertainty about whether this rise is going to endure or if it is a temporary discontinuity in the statistical data series.

It can be seen from the above list that effective backloading of HGVs is a key to improving the overall vehicle utilisation and minimising the percentage of kms run empty. Although it becomes an increasingly common practice in the road freight industry, there is still a significant proportion of vehicles returning to base without a load. A survey of 46 companies conducted by (Davies et al., 2007) shown that 4% of respondents did not backload their vehicles, 21% did it sometimes and 75% always tried to find a backload. The reasons for not backloading vehicles included (in the descending order of importance):

- Demand at base is too high
- Rates available for backhauls are too low
- Limited trust to unknown companies

- Time limitations – available loads take too long to load and deliver
- Short distance over which a backload is moved (the distances where specified ranged from 80 to 120 miles)
- No time to search for backloads
- No loads were available

Also McKinnon (1996), based on an interview survey of 73 manufacturers and 23 retailers, identified a number of factors inhibiting backloading (in the descending order of importance):

- **Requirements of the outbound delivery service** – as the main objective of a logistics operation is to satisfy customer service requirements, priority is given to outbound deliveries, especially if a company operates in a strict JIT environment. Gorick (2006) emphasises that ‘wasteful’ JIT deliveries need to be rethought if further reductions in empty running are sought. More frequent deliveries and smaller order sizes within narrow delivery windows impair vehicle utilisation both in terms of empty running and lading factor (Ferne et al., 2000).
- **Internal management structure**, particularly lack of co-ordination between purchasing and logistics departments that may result in many backloading opportunities being unnoticed
- **Incompatibility of vehicles and products**, as well as the risk of cross-contamination between products moved may limit the backloading opportunities.
- **Need to recover handling equipment / packaging** – equipment such pallets, roll cages, trays etc. and some packaging materials are increasingly transported back upstream for reuse or recycling. This limits the possibilities of picking up other backloads.
- **Unreliability of backloading operation** – ensuring effective backloading operation very much depends on a high level of journey time predictability, particularly when the backload needs to be collected within a specified time window (Fowkes et al., 2004). The increasing level of traffic congestion is significantly impairing the efficiency of logistical activities (McKinnon, 1998a, 1999a). In the UK, congestion is a major source of journey time unreliability contributing to around one-third of the total delay time in road freight transport (McKinnon et al., 2008a, 2009).

- **Poor matching of locations and schedules** – for example working practices such as booking-in schedules or opening times can make picking up a backload impossible.
- **Limitations of the route scheduling system** – some older routeing systems do not offer an option to incorporate return loading, particularly if this involves a diversion from the main route. As new systems are developed to allow for scheduling more sophisticated routes in a user-friendly manner, this is becoming less of an issue.

Further, McKinnon and Ge (2006) add inadequate knowledge of available loads and resource constraints (e.g. a shortage of truck drivers and the application of the EU Working Time Directive (WTD) to mobile workers in 2005) to the above list. Pettit et al. (2005) do not mention empty running in particular but confirm that the application of WTD to truck drivers is going to result in reduced amount of driving they are able to do and increase overall distribution costs.

Only modest opportunities for a further increase in backloading practices were identified in a modelling exercise undertaken by McKinnon and Ge (2006) for the UK grocery sector. It resulted in suitable backloads being identified for only 2.4% of the empty journey legs. That represents only 2% of empty lorry kms, which suggests that the potential for reducing empty running was somewhat limited. As McKinnon and Ge (2006) conclude this “highlights the effects of operational constraints on backloading, particularly, where the average length of haul is short, the scheduling is tight and a large proportion of freight require refrigeration” (p.408).

Further, numerous collaborative initiatives to reduce empty running are discussed in the literature. Mason et al. (2007) argues that a more collaborative approach to transport management is needed to reduce empty running and improve vehicle fill. They advocate combining collaboration with vertical supply chain partners with collaboration on a horizontal basis (e.g. in a form of factory gate pricing or pallet networks) to maximise synergies in improving logistics performance. A survey conducted by Cruijssen et al. (2007) indicated that an increase in a company’s productivity, especially decrease in empty running, was the most commonly indicated benefit of horizontal collaboration.

Surprisingly, there is virtually no difference in the percentage of empty running for the own account and hire and reward operators. Moreover, the average levels of empty running for the two groups of operators have remained very similar over the past two decades (McKinnon and Ge, 2006). As third party operators are in the core business to provide freight transport services and have a greater range of cargos for which to compete, theoretically they could be expected to be more efficient than operators that focus on delivering their own loads (Davis, 2008). However, this is clearly not the case. Consequently, the changes in the level of outsourcing of transport function are unlikely to have much impact on the overall empty running figure (McKinnon and Ge, 2006).

Lading factor

Lading factor is expressed as a ratio of the actual weight of goods to the maximum weight that could have been carried on a laden trip. The average load factor declined in the UK from 66% in 1984 to 58% in 2008, reaching its lowest point at 56% in 2006. The lading factor has been consistently higher for articulated than for rigid vehicles (Figure 3.12).

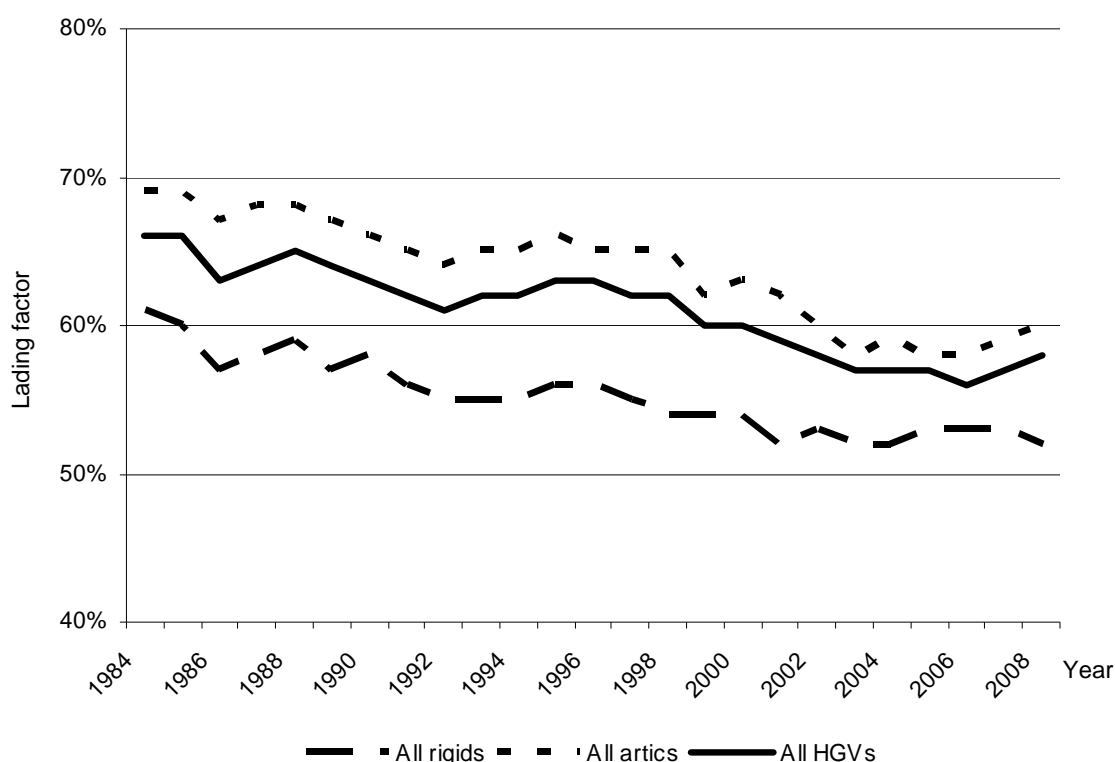


Figure 3.12. Lading factor
Source: Department for Transport, 2009a

As the lading factor is a weight-based measure, it gives no indication of how the vehicle loading has changed in terms of cubic volumes carried. Also, as it is expressed as a

percentage of available vehicle capacity, the changes in the maximum permissible weight and dimensions of HGVs have affected the lading factor over the years. For example, McKinnon (2005) suggests that the increase in maximum truck weight to 44 tonnes in 2001 might have reduced the average lading factor. This is because many hauliers started licensing their trucks at the maximum legal weight limit in order to have the flexibility to carry heavier loads when an opportunity arises, even if they normally do not do so.

Figure 3.13 shows the trend in the average weight carried per HGV journey. The average payload weight was calculated by dividing tonne-kms by laden vehicle kms. As can be seen, the average load increased gradually to 10.1 tonnes in 2008. Inverse relationship between average load and lading factor confirms McKinnon's (2005) hypothesis of maximum potential carrying capacity growing faster than actual average load. Interestingly, although average loads for rigid and articulated vehicles had been declining until mid-1990s, there was an overall increase in the average load weight over that time. This can be explained by the changes in the composition of the national fleet. An increasing proportion of larger vehicles carrying heavier loads in the GB fleet more than offsets the decrease in the average weight of a load carried by a given type of a vehicle.

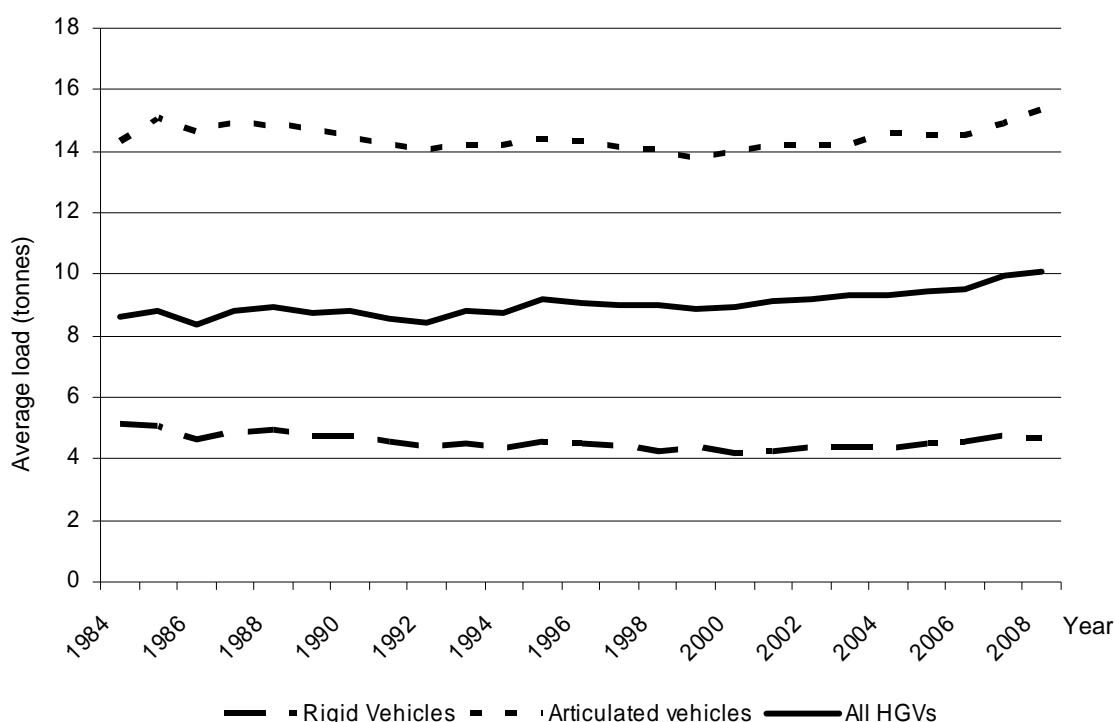


Figure 3.13. Average load carried on laden trips.
Source: Department for Transport, 2009a

From an international perspective, the average truck payload weight in the EU in 2007 was 10 tonnes (Piecyk and McKinnon, 2009a). This suggests that the typical load moved in GB is equal to the European average. Equal payloads weights do not mean, however, that vehicles are utilised to the same extent across different parts of Europe, as the carrying capacity of HGVs may vary. Unfortunately, the direct estimates of the lading factor are not available for the vast majority of the countries.

Factors influencing lading factor

According to McKinnon (2006a), the declining levels of vehicle loading can be attributed to the following constraints:

- **Demand fluctuations** – when a company faces variable demand, the vehicles acquired with sufficient capacity to accommodate peak orders, will inevitably be running with excess capacity during low-season periods.
- **Just-in-time (JIT) delivery** – when more frequent replenishment of supplies in smaller quantities is required, this tends to depress vehicle loading. Also tighter delivery constraints may be imposed, such as narrow delivery windows, to synchronise transport more closely to internal operations in factories, distribution centres and shops. This also links to the next point.
- **Unreliability of delivery schedules** – if schedules are unreliable, due to for example road congestion, more vehicles may be needed to serve a given number of delivery points within the required period. As a result, these vehicles will be travelling only partially loaded.
- **Vehicle size and weight restrictions** - as lading factor is an exclusively weight-based measure, it may underestimate the actual utilisation of vehicles as an increasing proportion of loads is volume, rather than weight-limited. Conversely, some high density loads reach the maximum weight limit before all the space in the vehicle is occupied. In 2008, 31% of tonne-kms carried by HGVs were limited by volume, while only 4% were limited solely by weight (Department for Transport, 2009a).
- **Health and safety regulations** may also constrain weight and dimensions of loads.
- **Capacity constraints at company premises** – sometimes the size of load is constrained by the storage capacity at one end of the trip, for example pallet stacking may be constrained by the standard slot height of warehouse racking systems.

As mentioned above, in many sectors, such as food, non-food retailing, parcels and automotive, loads are constrained by volume rather than by weight because of the low density of goods transported. Weight-based measures of vehicle loading give, in such cases, a misleading impression of the underutilisation of available vehicle capacity. Thus, volume-based measures are more appropriate in such sectors (McKinnon, 2009b). Vehicle loading in terms of payload weight, pallet numbers and average pallet height is measured in the UK government- sponsored transport key performance indicator (KPI) programme. A KPI survey of road transport in the food supply chain carried out in 2002, showed that, in terms of volumes, on a loaded trip on average 69% of the deck area and 76% of the height were utilised, resulting in a mean loading space utilisation of 52% (McKinnon and Ge, 2004). The 2007 KPI survey in the food sector found that the average deck utilisation, measured as the available pallet positions occupied, was 75%, an increase by 8.7% since 2002. The mean height utilisation figure was 72%, resulting in the overall space utilisation of 54%, a slight improvement by 3.8% from the 2002 level (Freight Best Practice, 2007c). By comparison, Leonardi and Baumgartner (2004) reported an average space utilisation of 60.7% in the German road haulage industry.

As up to 28% of tonne-kms moved in GB are not limited by either weight or volume (Department for Transport, 2009a), there is still a significant scope for further improvements in vehicle utilisation. McKinnon (2000, 2008) listed the following measures to improve vehicle loading:

- Use of more space-efficient handling systems and packaging.
- Consolidation of loads in larger / heavier vehicles, for example through the use of double-deck road trailers.
- Adaptation of more-transport-efficient order cycles, for instance concentrating distribution in certain areas on ‘nominated’ days or implementing a system of rolling credit instead of the traditional monthly payment cycle.
- Inter- company collaboration, both vertically as well as horizontally across supply networks.
- More flexible approach to scheduling.

Additionally, Baumgartner et al. (2008) argue that, in addition to minimising the distance travelled, computerised routing and scheduling and vehicle telematics offer also a great potential to improve average vehicle loading and, thus, the environmental performance of a fleet, particularly in terms of CO₂ emissions. Vehicle utilisation can

also be influenced by the way goods are stacked on pallets, which type of pallets is used and how pallets are loaded onto a vehicle (A.T. Kearney, 1997). Optimisation models are typically used to solve problems of arranging products on pallets and arranging pallets on lorries (e.g. Dowsland, 1993, Bischoff and Ratcliff, 1995, Morabito and Morales, 1998, Morabito et al., 2000). However, the theoretical results obtained from these models are likely to be undermined to some extent by the requirements of the ‘real-world’ for instance a requirement to use a certain type of pallets for a particular customer.

The trends in the two key variables determining vehicle utilisation, i.e. empty running and lading factor seem to have reversed their longer-term directions in a last few years in the UK. Empty running has been increasing since 2003, despite increasing attention and numerous industry initiatives aimed at reducing it. The lading factor increased by 2% (in absolute terms) over the last two years. This should help companies to at least partially offset the negative consequences of empty running.

3.5.5. Fuel management

Fuel management focuses on two main ratios, namely fuel efficiency and carbon intensity of fuel used.

Fuel efficiency

Energy efficiency of road freight transport can be measured in two ways. Energy (i.e. fuel) consumed may be expressed in relation to the distance travelled (e.g. kms per litre) or to the amount of freight movement (e.g. tonne-kms per litre). The former measure is referred to as fuel efficiency, whereas the later one is usually called energy intensity (Ruzzenenti and Basosi, 2009, McKinnon, 2010). It also needs to be stressed here that fuel efficient operation does not necessarily have to be the least energy intensive as fuel efficiency can vary independently of the utilisation of vehicle capacity (McKinnon et al., 1993, McKinnon, 2009b). As issues regarding vehicle utilisation were discussed above, this section focuses solely on fuel efficiency.

Fuel efficiency data for road freight transport have been collected by the Department for Transport since 1989. However, the fuel consumption figures for 1993 have been revised “as a result of quality improvements and methodological changes” (Department for Transport, 2009a, p.159). Thus, data for 1992 and earlier years are not comparable

with the later series. Since 1993, articulated vehicles have become increasingly fuel efficient with the average distance travelled per a litre of fuel increasing from 2.5 kms in 1993 to 2.8 kms in 2007. For comparison, in the US, the efficiency of medium and heavy trucks improved only modestly from 2.4 km/litre in 1966 to 2.5 km/litre in 2006 (Sivak and Tsimhoni, 2009). The average fuel efficiency for the British-registered rigid vehicles, on the other hand, has decreased from 3.4 km/litre in 1993 to 3.3 km/litre in 2007 (Figure 3.14). Kamakate and Schipper (2009) analysed the truck freight energy use in five different countries between 1970 and 2005. For the UK, they report an 11% increase in fuel intensity (expressed as megajoules (MJ) per km), thus declining fuel efficiency, over that period. This contradicts the analysis by McKinnon (2007b), who reports that “between 1990 and 2005 average fuel efficiency across the entire UK truck fleet increased by roughly 10.5%” (p.36).

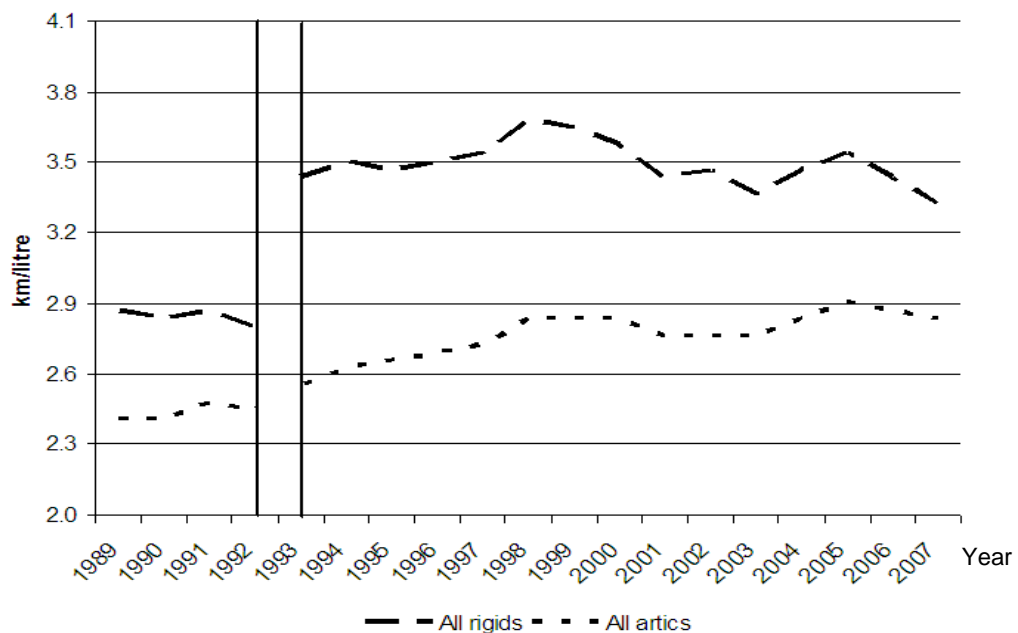


Figure 3.14. Fuel efficiency (km/litre)
Source: Department for Transport, 2009b

In the UK, fuel constitutes around 32% of annual vehicle operating costs (Burns Inquiry, 2005) and this can rise to over 35% during periods of high oil prices (McKinnon, 2010). As fuel prices in the UK are already the highest in Europe (24% above the EU15 average in 2006), further increases give operators a strong incentive to improve the fuel efficiency of their fleets (McKinnon, 2007c). Relying on high fuel price to encourage companies to improve their fuel efficiency, however, may not be sustainable in the longer term as the industry is already suffering the effects of increased foreign competition. Carriers from abroad refuel their trucks before entering the

country, with virtually no purchases being made in the UK (Piecyk and McKinnon, 2007, Piecyk et al., 2010). Benefiting from cheaper fuel prices in continental Europe, they can offer lower freight rates, reducing the profitability of operations for British hauliers (Burns Inquiry, 2005).

It is very likely that oil prices will continue to grow steeply in the future (McKinnon, 2010). Logistics systems designs and sourcing strategies are relatively insensitive to the price of fuel and generally do not change significantly until energy prices become extremely high (Schutt, 1982, Acharya et al., 2009). For example, Gosier et al. (2008) presents a theoretical case study showing that a 167% increase in oil prices would be needed to change the optimal number of DCs from five to seven. Until oil price rises are large enough to trigger system or structural changes, they are likely to induce transport efficiency improvements within the existing networks. Hence, improvements in fuel efficiency are likely to yield significant economic and environmental benefits for businesses.

Improving fuel efficiency

According to Ang-Olson and Schroeder (2003), “in a typical modern diesel truck engine, 53% of the fuel energy is lost as heat through the exhaust system and cooling system, and another 5% is dissipated through engine friction and pumping losses, leaving 42% available as engine output” (p.4). Further, this energy is used to overcome the following factors:

- Aerodynamic drag
- Rolling resistance
- Drive train friction
- Operation of ancillary equipment
- Inertial forces (during acceleration or climbing).

The contribution of each of these factors to energy losses depends on operating speed, vehicle weight, terrain, driver behaviour, weather and pavement conditions, etc. (Ang-Olson and Schroeder, 2003). Thus, these are the areas that should be targeted when fuel efficiency improvements are sought. Leonardi and Baumgartner (2004) classify fuel efficiency measures into four categories:

- **Logistics efficiency** – focused on ensuring optimal loading of vehicles, selecting the most suitable vehicle category and optimising all transport links from the point of origin to the final destination.
- **Vehicle efficiency** – focused on vehicle technology, design and maintenance.
- **Driver efficiency** – focused on training and / or assistance from on-board units used for measuring components of driving behaviour that influence fuel use.
- **Route efficiency** – focused on ensuring optimal routing based on information on itinerary, road and traffic conditions, etc.

The measures to improve logistics efficiency were discussed in the section on vehicle utilisation. Hence, the focus in this section will be on vehicle, driver and route efficiency.

Vehicle efficiency

The technical refinements to HGVs have significantly enhanced the fuel performance of trucks over the past decades, with the greatest improvements made in the 1970s and 1980s. Since 1990s, however, the improvements from the developments in vehicle technology have been relatively slow (McKinnon, 1999b). Tightening emission controls on other pollutants (Euro-emission standards) compromised further improvements in fuel consumption to some extent and this is likely to continue in the future. It was estimated that further reductions in nitrogen oxides and particulate matter emissions (i.e. introduction of Euro 6 standard in 2013) can carry up to 10% fuel penalty (European Commission, 2007a, Keenan, 2008). Nevertheless, there are attempts to achieve further energy savings through increased fuel economy for new HGVs, for example through introducing fuel economy standards (Langer, 2004). So far only Japan has adopted mandatory HGV fuel economy standards to reinforce improvements in vehicle technology. Legislation introduced in 2005 in Japan requires an average 12% improvement in fuel economy in 2015 compared to 2002 for new trucks.

Further opportunities for increasing fuel efficiency of HGVs should be sought through a number of modifications in vehicle design rather than through relying solely on technical advances in combustion performance. Modifying the shape of the vehicle can yield significant savings in fuel consumption by reducing air resistance (McKinnon, 2010). While new trucks show significant ‘air flow’ design improvements, a number of aerodynamic features (e.g. roof deflectors, cab extenders, side fairings) can be

retrofitted to existing vehicles at a relatively low cost (Komor, 1995, Ang-Olson and Schroeer, 2003, Freight Best Practice, 2007d,e). Fitting suitable aerodynamic devices to a vehicle can improve fuel efficiency by 6-12% (Freight Best Practice, 2007d,f). The trailer design can also significantly impact fuel consumption. For example, Marks & Spencer reported a 10% improvement in fuel efficiency from introducing aerodynamically advanced teardrop trailers that slope downwards at the front and rear (Freight Best Practice, 2009). The aerodynamic design is not the only measure to reduce fuel consumption. Lower rolling resistance tyres can improve fuel consumption by 4-13% resulting in significant cost savings (Freight Best Practice, 2006a, 2007g).

Also, reducing the tare weight of a vehicle can lead to significant improvements in its fuel efficiency. Leonardi and Baumgartner (2004) note that differences in the tare (i.e. empty) weight can be considerable. They report that, across a sample of 50 haulage companies, the average tare weight of a 40-tonne gvw lorry was 14 tonnes while a minimum weight was 11 tonnes. Fuel leaks in the supply or injection systems, misaligned or under-inflated tyres or engine faults can significantly raise fuel consumption. Frequent vehicle servicing and preventive maintenance are thus extremely important in ensuring fuel efficient operation. Good vehicle maintenance, along with driver training, was considered to be the most important measure of improving fuel efficiency by the hauliers surveyed by McKinnon et al. (1993).

Driver efficiency

Driving style is the single greatest influence on vehicle fuel consumption. Thus, training should be a successful way of implementing and popularising fuel efficiency initiatives amongst truck drivers. Driver training is also the most cost effective way of cutting fuel consumption. In 2003, the UK government initiated The Safe and Fuel Efficient Driving (SAFED) programme. Between 2003 and 2008, some 12000 truck drivers were trained under the scheme (SAFED, 2008). Average fuel savings of 4-5% were recorded following the training, with some of the companies experiencing improvements in fuel efficiency as high as 9-12% (Freight Best Practice 2008a). Further, McKinnon et al. (1993) argue that “for training to have a lasting effect, drivers need to be continually motivated to drive in a fuel efficient manner” (p.9). Drivers’ performance should be monitored and regular feedback needs to be given. Financial incentive schemes can be implemented as a formal encouragement for drivers to save fuel. Incentive schemes are proven successful in helping to “maintain awareness of the fuel efficiency issue and

incentivise drivers to continue using their skills in fuel-efficient driving” (McKinnon, 2010, p.329).

Route efficiency

Road type and traffic conditions can largely affect fuel efficiency. Less smooth driving with often gear changes, braking and accelerating results in increased fuel use (Freight Best Practice, 2006b, 2008b). The use of CVRS packages, as discussed above, can significantly reduce the distance travelled and should consequently result in lower fuel consumption. However, the shortest route may not necessarily be the most fuel efficient one, as it may involve driving in hilly terrain or congested urban areas. While it is possible to optimise routes in terms of fuel consumption, McKinnon (1999b) reported that no examples of so doing had been found in practice.

Traffic congestion also impairs truck fuel efficiency. With the congestion expected to increase significantly in the future (Department for Transport, 2008e), minimising fuel consumption is likely to become more important criterion of route selection. From the policy making perspective, a radical solution to this problem would be separating cars and trucks onto different traffic lanes or routes as investigated for example by de Palma et al. (2008). The possibilities to implement this measure, however, may be limited through other traffic management requirements, e.g. cyclist safety or dedicated bus lines.

Surprisingly, despite expected high returns and relative ease of implementation, almost one-third (27%) of companies interviewed in Germany by Leonardi and Baumgartner (2004) reported that they have not introduced any fuel efficiency measures. No similar data exists for the UK. Technical improvements such as synthetic oils, wind spoilers or low rolling resistance tyres proven to be the most popular with over a half of respondents indicating an intention to implement at least one such a measure. Therefore, there seems to be a great potential for further fuel efficiency savings within the industry. A recent study by RICARDO (2009) for the UK Department for Transport identified aerodynamic trailers, vehicle platooning (i.e. HGVs driving in a close proximity to each other on motorways to create a train) and SAFED driver training as having the greatest potential to reduce fuel consumption and related CO₂ emissions.

Carbon intensity

Currently, diesel fuel is the main source of energy for road freight transport throughout the world. Burning one litre of diesel fuel emits 2.6391 kg CO₂ (DEFRA, 2009). One way to reduce CO₂ emissions from road freight transport is to switch to less carbon intensive fuels. These are commonly referred to as alternative fuels. Alternative fuels include biofuels and other alternative fuel sources e.g. natural gas, electricity or hydrogen. According to the International Energy Agency (2004), biofuels can be defined as follows: “either in liquid form such as fuel ethanol or biodiesel or gaseous form such as biogas or hydrogen, biofuels are simply transportation fuels derived from biological (e.g. agricultural) sources” (p.26).

There are two main types of biofuels (Freight Best Practice, 2006b, Cullinane and Edwards, 2010):

- **Biodiesel** – a substitute for diesel oil. It is made from plant or animal oils through transesterification, in which oil is reacted with alcohol in the presence of a catalyst to produce biodiesel and glycerine (Johansson, 2003).
- **Bioethanol** – an alcohol based substitute for petrol. It can be made from any biological foodstock that contains sugar or materials that can be made into sugar, such as starch or cellulose. The production is based on biological processes using yeast and bacteria (Johansson, 2003). Sugar beet and corn are the main raw materials, with 80% of all bioethanol produced worldwide in 2007 extracted from these two crops (Sperling, 2008).

In terms of carbon intensity, however, the reduction in CO₂ emissions attributable to biodiesel can only be assessed on a life-cycle basis. The exhaust CO₂ emissions are comparable for bio- and conventional diesel fuel (Environmental Protection Agency, 2002) with some of the recent studies suggesting even a 10% increase in the tailpipe CO₂ emissions when using biodiesel (Department for Transport, 2007b). This is because of the lower heat value of biodiesel which results in lower fuel efficiency (Lopez et al., 2009). It is the carbon sequestration effect of growing the plants to produce biodiesel that contributes to lower CO₂ emission factors for biodiesel. The full impact of biofuels still remains uncertain. Using a worldwide agricultural model that takes account of land-use changes, Searchinger et al.(2008) found that “corn-based ethanol, instead producing 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years. Biofuels from switchgrass, of grown on U.S.

corn lands, increase emissions by 50%” (p.1238). Similarly, Fargione et al. (2009) show that biodiesel, if produced on converted tropical rainforest in Indonesia and Malaysia (these two countries currently account for 86% of global palm oil production), could increase greenhouse gases for up to 86 years when compared with refining and using the fossil fuels it typically displaces. McKinnon (2008) the adverse effects of land conversion necessary for biofuel production may be overcome by use of ‘second-generation’ biodiesel “derived from waste and forest products grown on land unsuited to agricultural production (..), though large-scale commercial production may take years to develop” (p.19). Thus, biomethane / biogas now seem more promising biofuels for trucks and vans.

Other alternative fuels include hydrogen, natural gas – compressed or liquid (CNG, LNG), liquid petroleum gas (LPG). However, their applications in HGVs are at present still limited (Parker and Pettijohn, 1997, Parker et al., 1997, Beresford et al. 2003, Freight Best Practice, 2006b). The main challenge to successful adaptation of alternative energy sources is ensuring the availability of relevant fuels. Thus, provision of storage facilities and refueling infrastructure is a key to wide industrial acceptance of a given energy option (Byrne and Polonsky, 2001, Beresford et al. 2003, Khare and Sharma, 2003). Also, availability of raw materials, as well as production and distribution costs are crucial (Johansson, 2003).

Electric vehicles are becoming increasingly popular around the world, despite still having relatively limited driving distances and lengthy battery charge times (Khare and Sharma, 2003, Rogers et al., 2007). There are two major advantages of electric vehicles – they emit virtually no tailpipe emissions and they are much quieter than conventional trucks due to fewer vibrations being produced (Sperling, 2003, Freight Best Practice, 2006b). This makes electric vehicles particularly suited for the demands of urban distribution (Langer, 2004, Cullinane and Edwards, 2010). Although electric trucks are virtually pollution free at point of use, their overall environmental performance depends on the source of electricity used to recharge the batteries (Johansson, 2003). Thus, “until electricity is produced from renewable sources, the burden of environmental damage is merely being transformed from the vehicle upstream to the electricity production process” (Cullinane and Edwards, 2010, p.316). Further, electric or hybrid (diesel-electric) engines are only likely to be used in rigid vehicles. The opportunities for application to long haul articulated lorries seem to very limited, except to power

ancillary equipment (McKinnon et al., 2010). Electrification of the vehicle body equipment such as refrigeration and refuse, although still limited to specific body types, offers a significant potential for CO₂ reduction (RICARDO, 2009).

It is important to note that in the case of alternative fuels, reduction of CO₂ emissions is not the sole objective and consideration needs to be given to the whole range of air pollutants. Different fuels present different composition of emissions, both on tailpipe and life cycle basis (Khare and Sharma, 2003 Sperling, 2003). Although minimising carbon emissions is a priority in preventing climate change, other health and non-health effects of air pollution associated with exhaust emissions need to be taken into account when deciding on a viable alternative fuel option.

3.6. Frameworks for Analysing the Environmental Impact of Logistical Decision-Making

As discussed in the earlier sections of this Chapter, the demand for road freight transport and associated externalities are not only a function of economic growth but are also influenced by logistical and supply chain structures and, thus, subject to complex and often counteracting pressures. In this section, the available literature on the frameworks for analysing the environmental impact of logistical decision making are reviewed.

1. Wandel and Ruijgrok (1993) introduce a five-layered model of how demand for freight transport arises. Their model consists of five functional layers (material flow, transport operation, informatics operation, transport infrastructure and telecommunications infrastructure) interacting on four markets (Figure 3.15).

In the material flow system, the total demand for freight transport services is created as a result of the movement of materials and goods by manufacturing or trading companies. The transport operations can be described as the flows of load units and vehicles within the system that can be then aggregated into the total supply of freight transport services. Supply and demand are matched in the transport market resulting in actual material and load unit flows. The transport infrastructure system is defined as ‘the physical infrastructure, guideways and interchanges, and the management of its usage’ (p.238). The freight transport flows and available infrastructure interact in the traffic market, creating actual vehicle movements. These three layers, i.e. the material flow, the

transport operation and the transport infrastructure, require information flows between entities within the system and infrastructure to facilitate this information and data exchange. Further, the layers in the model represent functions and not organisational boundaries so one organisation may cover several functional levels.

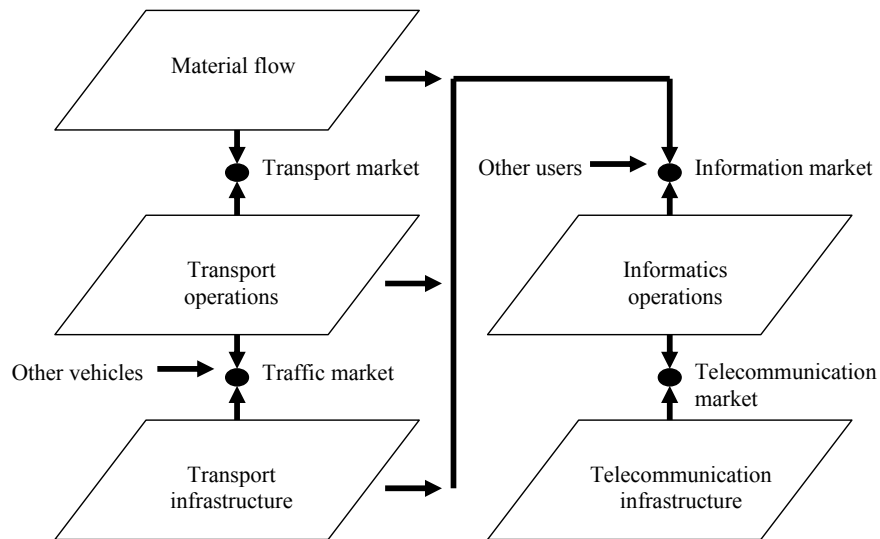


Figure 3.15. A five-layer model of road freight transport
Source: Wandel and Ruijgrok, 1993

Further, according to Wandel and Ruijgrok (1993), this transport system is influenced by a number of external factors broadly classified as economic, technological and public policies developments. These factors require planning and decision activities affecting the structure, components and management of the transport system. ‘Structure’ comprises physical transport infrastructure as well as organisational and supply chain networks. Components are ‘objects’ within the system, e.g. vehicles, machines, manpower, IT systems, traffic signs etc. Management activities include allocation of resources, delivery routeing and scheduling, traffic management etc. There are also a number of impacts resulting from the material flow, transport operation and infrastructure, some beneficial such as creation of economic value-added, others detrimental such as increased emissions, noise, congestion, accidents and land use.

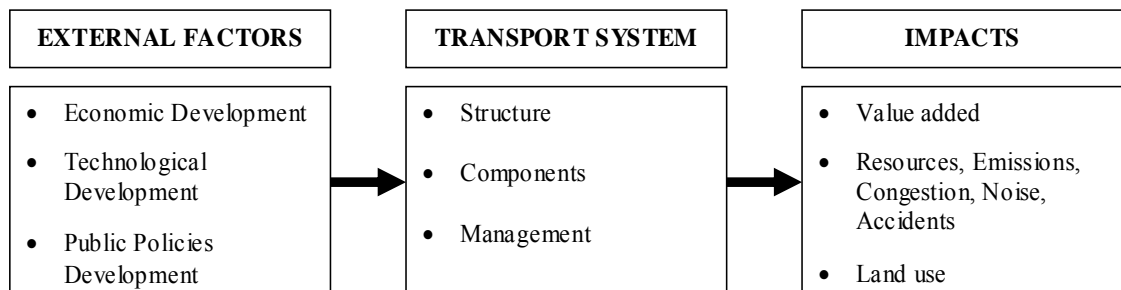


Figure 3.16. External factors, decisions and impacts of freight transport
Adapted from: Wandel and Ruijgrok, 1993.

2. McKinnon and Woodburn (1993, 1996) and (McKinnon, 1998b, McKinnon, 2001) argue that the demand for road freight transport is the result of a series of decisions made at different levels within the corporate hierarchy. They differentiated four levels of logistical decision-making within a company, each of which will be influenced by a set of factors:

- **Structural factors** determining the number, location and capacity of factories, warehouses and other facilities in the logistics system;
- **Commercial factors** related to companies' sourcing and distribution strategies and policies;
- **Operational factors** affecting the scheduling of product flow;
- **Functional factors** relating to the management of transport resources – usually regarding the choice of vehicle, planning of loads and routeing of deliveries.

The complex interactions between decisions made at these four levels largely determine the amount of road freight traffic. Also, while the structural and commercial factors affect mainly the number of tonne-kms, the operational and functional factors influence the vehicle kms travelled (McKinnon, 1998b). Ruijgrok (2001), for example, adapts the framework introduced by McKinnon and Woodburn (1993, 1996) to investigate supply chain trends in Europe. He also stresses that logistics decisions influence the demand for freight transport, e.g. centralisation of inventory is likely to result in an increase of the average length of haul. Moreover, in the REDEFINE report (1999), one more category is added to this classification, namely factors affecting **product configuration**, i.e. changes in the design of a product which can affect its value density and logistical requirements.

Lemoine and Skjoett – Larsen (2004) also list product-related factors as one of the aspects shaping the intensity of transport activities and suggest that 'the demand for transport is influenced not only by company specific logistics and marketing strategies, but also by characteristics of the products and supply chains involved' (p.809). They also stress the importance of external factors, such as road taxes or traffic congestion in shaping transport demands.

3. Drewes-Nielsen et al. (2003) extend the model presented by McKinnon and Woodburn (1993, 1996) and McKinnon (1998b, 2001). The four-level structure is supplemented by one more dimension, namely external influences. Their extended

model illustrates how changes in logistical organisation influence the pattern of transport and its environmental impacts (Figure 3.17). The authors also suggest that in real life this model should be supplemented by a feedback mechanism illustrating the circular nature of the decision making process (e.g. the pollution caused by transport might cause government intervention giving new conditions for transport and inducing a new ‘logistical regime’).

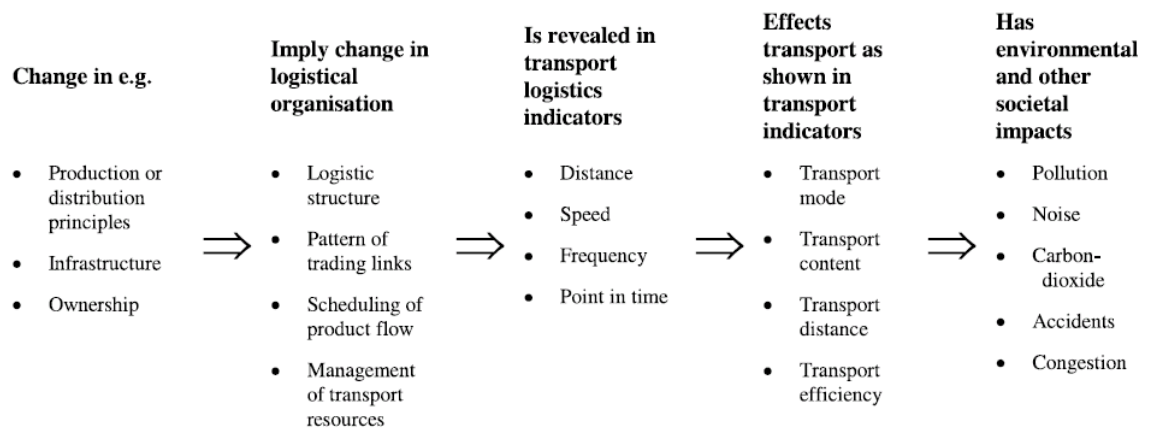


Figure 3.17. Relationship between logistical organisation and transport – a theoretical framework
Source: Drewes-Nielsen et al. 2003

4. Aronsson and Huge Brodin (2006) propose a funnel-model which illustrates how decisions at different levels both create opportunities and set limitations for decisions made on another level. Their model extends the traditional levels of strategic, tactical and operational decision making by adding choices concerning product design stage to the framework. “Once the product is designed, e.g. the weight and volume of the product is known. Those characteristics then provide opportunities and set limitations as to how the overall logistics systems can be designed” (p. 401). However, it should be noted here that, conversely, the characteristics of a logistics system already in place should be considered at the product design stage (Dowlathshahi, 1999, Gupta and Dutta, 1994), particularly when the environmental sustainability of supply chain operation is to be taken into account as recommended by Wu and Dunn (1995).

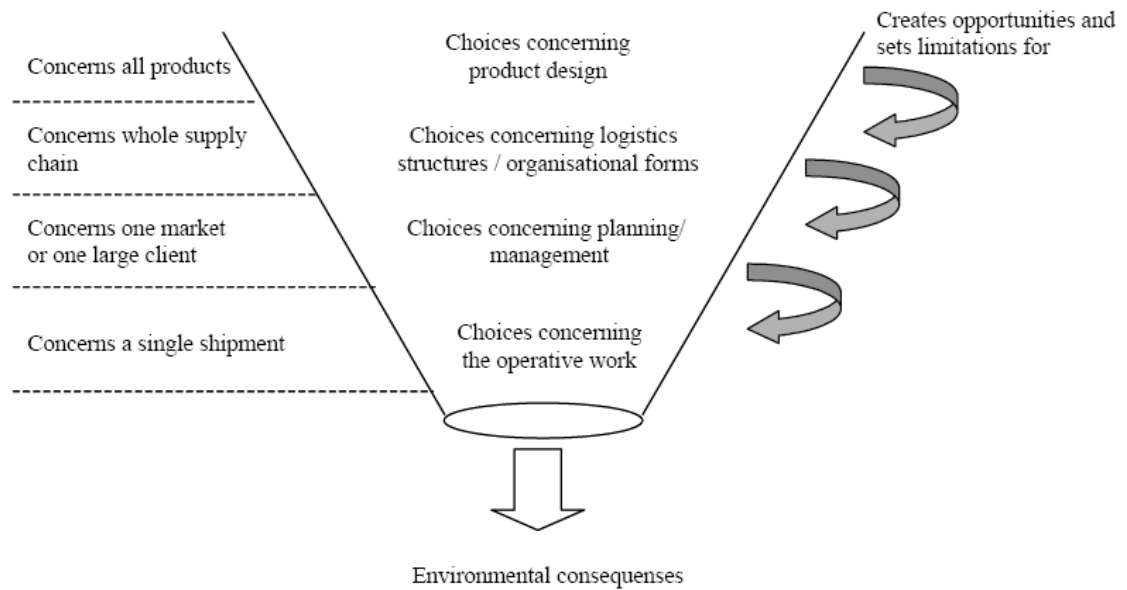


Figure 3.18. Framework model describing different logistics decision levels and their funnel-like relationships

Source: Aronsson and Huge Brodin, 2006

The models discussed above typically consider the demand for freight transport as a function of the structure, components and management of a logistics or supply chain system. This is sometimes extended to include also the nature and characteristics of products handled and / or external influences from outside the system considered. Thus, for the purpose of this thesis, the framework proposed initially by McKinnon and Woodburn (1993, 1996) and (McKinnon, 1998b, McKinnon, 2001) consisting of **structural, commercial, operational** and **functional factors**, has been extended to include two further categories:

- **Product-related factors** affecting the nature of the transport operation;
- **External factors** – such as government regulations and tax policy, wider macroeconomic trends, market dynamics and advances in technology.

All factors influencing the key logistics variables, as discussed in the proceeding sections, can be assigned to one of the above categories. The six sets of factors have a complex inter-relationship with the key freight transport variables and outputs. The framework linking economic growth, road freight traffic and CO₂ emissions shown in Figure 3.7. has been extended to illustrate these linkages (Figure 3.19).

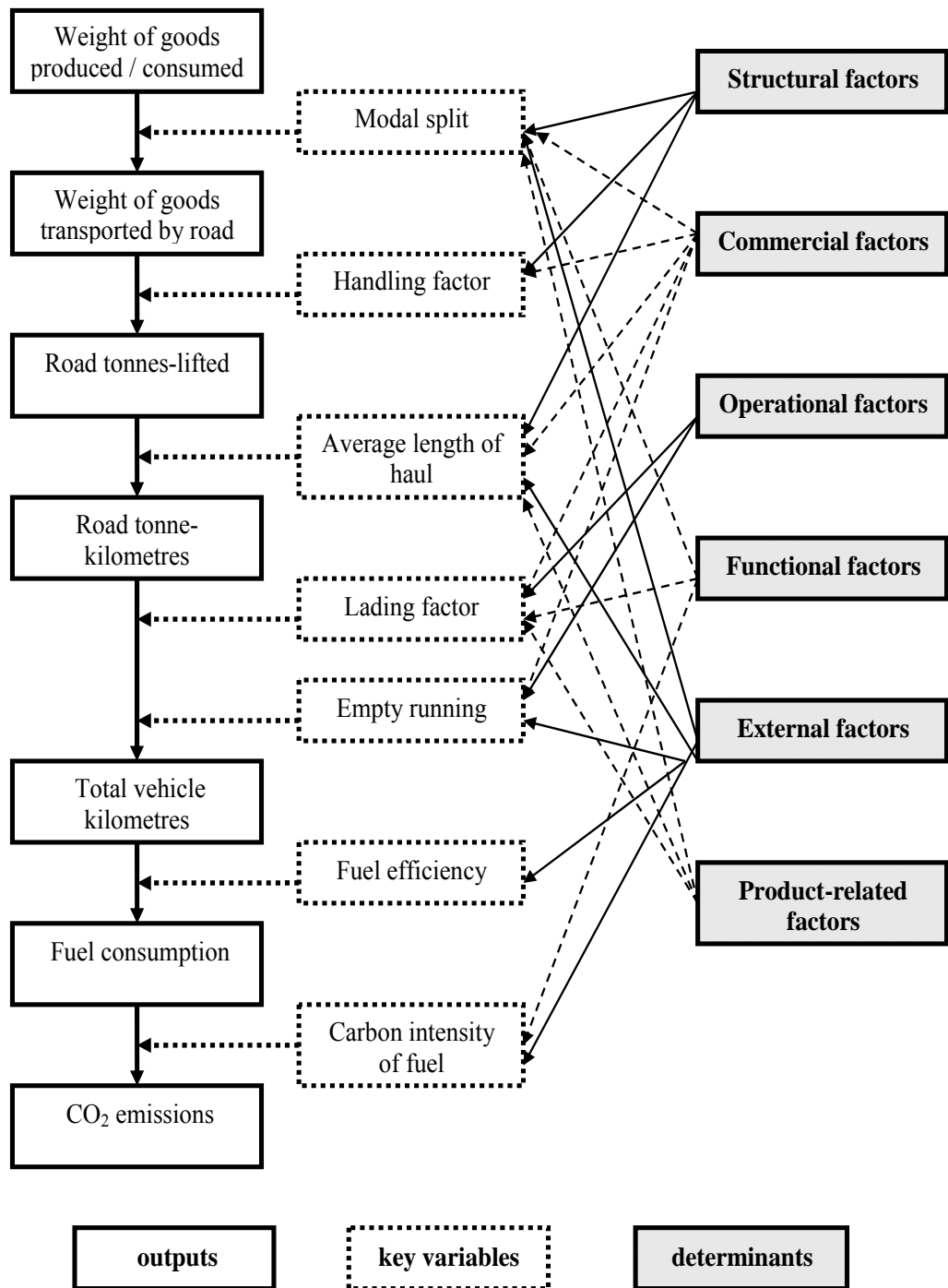


Figure 3.19. Relationship between logistical variables, determinants and environmental impacts

Each set of factors exerts an influence on more than one variable, while some have a pervasive effect on most of the variables. Structural factors determine the location of facilities in a logistics system and, thus, the average distance between them and the number of times a product is being handled along the supply chain. Location decisions can also limit the potential for using alternative transport modes. Commercial factors such as sourcing and distribution strategies have an influence on freight transport modes

used, handling factor, average length of haul and vehicle utilisation. Scheduling of product flow (i.e. operational factors) impacts mainly on empty running and lading factor. Functional factors relating to the management of transport resources influence modal split decisions, vehicle utilisation and fuel management. External factors have a potential impact of every variable in the framework and factors related to the design and nature of products are likely to exert influence on lading factor, average length of haul and modal split. The framework is also discussed in Piecyk and McKinnon (2010).

3.7. Conclusions

There is no single technological solution which will reduce CO₂ emissions from UK road freight transport by a large enough margin to meet government climate change targets. Reducing the carbon dependency of road freight transport will also require a range of other measures including increased use of alternative fuels, greater fuel efficiency, better vehicle utilisation and a switch to greener transport modes. Also, in terms of transport policy interventions, “changes in fuel price and vehicle purchase taxes do not appear to be effective instruments for reducing energy consumption for this end use, alternative policy options, including less-carbon intensive fuels and technologies, and reduced congestion, appear to be better choices” (Greening et al., 1999, p.331).

The aim of this Chapter was to review the literature on the key variables and factors influencing levels of road freight transport and associated CO₂ emissions. The link between economic growth and road freight transport activity was investigated and then disaggregated into a series of key logistics ratios. The factors likely to influence each ratio were also reviewed and then classified into six possible categories, i.e. structural, commercial, operational, functional, external and product-related factors. As a result, a comprehensive analytical framework was developed to underpin the empirical research. This framework constitutes a valuable tool for a comprehensive system analysis. It enables estimation of the environmental impacts of present road freight transport activity and can also be used to forecast changes in CO₂ emissions resulting from modifications to the system in the future.

This framework can also be used to assess the relative effect of a range of decarbonisation measures in the UK freight sector. For instance, McKinnon (2005) argues that “given the current modal imbalance, measures which aim to rationalise road

freight transport operations can potentially yield greater environmental benefit than marginal changes in the modal split” (p.78). Based on the UK example, McKinnon (2000) shows that a 10% increase in truck loading or a reduction in the empty running of trucks by 4% (in absolute terms) would yield significantly higher savings in energy consumption than the doubling of rail freight traffic. Also the inter-functional relationship between transport and other supply chain activities such as for example production, purchasing, marketing, inventory management and warehousing has a major influence on companies’ overall environmental performance. Companies often prioritise these other activities over transport efficiency, as the costs or benefits of so doing are much greater than the costs of sub-optimal transport utilisation (McKinnon, 2003).

Furthermore, McKinnon and Woodburn (1993) argue that “it would be wrong to judge the credibility of official road freight forecasts merely on the basis of historical precedent. It is possible that, quite independently of any policy initiatives, the *process* of traffic growth will change in future years, making it very unwise simply to extrapolate past trends” (p.466). Hence, the forecast should be rooted in “a detailed understanding of the causes of freight traffic growth” (p.466). Thus, it is important to consider all aspects of logistical decision making and their likely impact on the environmental performance of the system. Comprehensive understanding of the likely consequences of decisions made at different levels in the organisational hierarchy allows managers to optimise their systems according to the selected criteria, ideally leading to better economic and environmental results. Full awareness of the links and trade-offs between key logistics variables results in the ability to envisage the ‘bigger picture’. For example, Kohn and Huge Brodin (2008) show that, although CO₂ emissions from transport activity are generally acknowledged to increase as a result of centralisation of the logistics system, under certain circumstances centralised distribution may prove beneficial in environmental terms. This is when the opportunities to make further changes in the way the system is operated, that were previously not possible in a decentralised network, are now noticed and exploited. Hence, the theoretical framework presented in this chapter has a wide practical applicability and supports managers in developing a comprehensive understanding of the broader consequences and opportunities arising from their decisions. It also provides a useful forecasting tool for estimating how changes in the design, structure and management of supply chains are likely to influence road freight traffic levels and associated CO₂ emissions in the future.

Chapter 4. Research Methodology

Aims of the chapter:

- *To present theoretical foundations of the research*
- *To explain the methodology chosen*
- *To outline the research design process*
- *To justify the research methods adopted*

In the previous chapters the theoretical context of the research project was established. The aim of this chapter is to present different philosophical perspectives shaping the researcher's perception of the world around them and to explain how these intellectual traditions have influenced the present study. Different research paradigms are introduced and their adaptation in logistics and supply chain discipline is reviewed. Highlighting the philosophical stance of the thesis provides justification of the methodology chosen. Later sections describe the resulting research design process and choice of research methods.

4.1. The Relationship between the Theoretical Perspective and Research Practice

This thesis is based upon the research project undertaken in the emerging field of green logistics. This research does not exist in isolation but it is a part of wider scientific and business reality. Thus, green logistics research, like all logistics and supply chain or even business or social science research, will be shaped by what is going on in the real world (Bryman, 2004, Remenyi et al., 2005, Bryman and Bell, 2007). It will also be influenced by the academic traditions of the discipline, as well as by the researcher's own set of intellectual beliefs and allegiances which in turn affects their perception of the nature of social or business entities and events (Alvesson and Deetz, 2001, Maylor and Blackmon, 2005). Thus, the way the researcher designs and conducts the research is determined by a range of factors that need to be considered to fully understand the process of scientific investigation.

A framework illustrating how the theoretical base determines the researcher's approach, choice of data collection methods, analytical approach and interpretation of the results (Bryman and Bell, 2007) is shown in Figure 4.1. Ontological and epistemological considerations underpin fundamental assumptions about the nature of social entities and

knowledge. They form the philosophical stance, often called the research paradigm, which lies behind the chosen research methodology (Crotty, 1998).

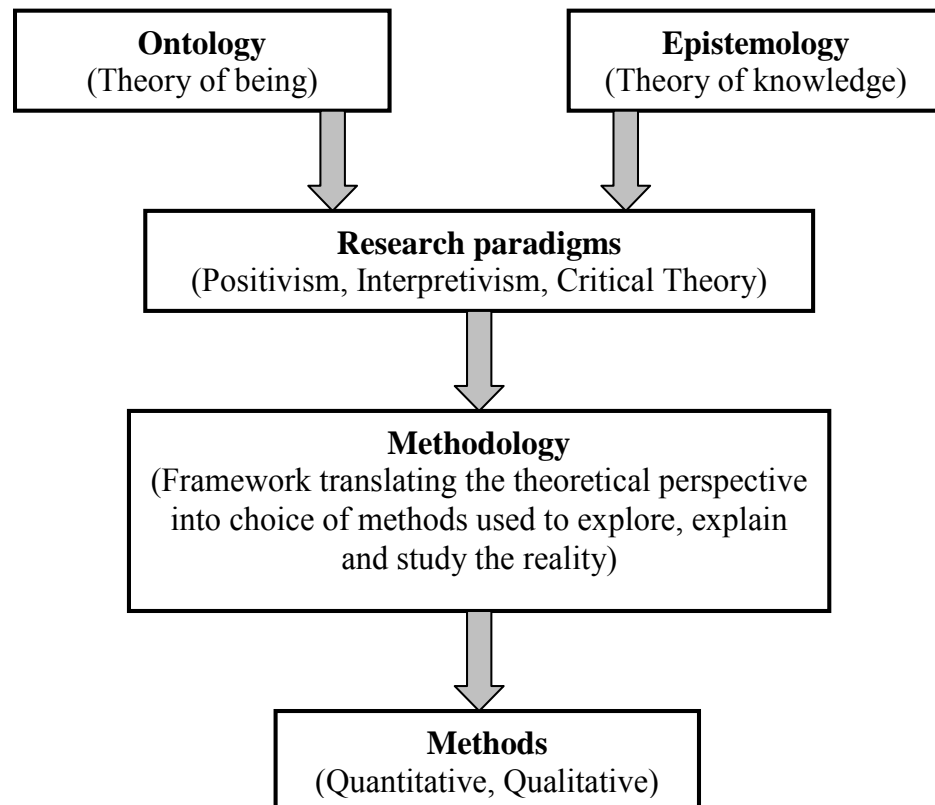


Figure 4.1. The relationship between the theoretical perspective and research practice
Adapted from: Crotty, 1998, Sarantakos, 2005

The methodology, in turn, translates the research paradigm into a set of principles that demonstrate how the world can be approached, explained and studied (Sarantakos, 2005). A research method is a tool the researcher uses to collect and analyse the data (Bryman, 1995, Saunders et al., 2007).

4.1.1. Philosophical foundations of research

Ontology and epistemology are branches of philosophy concerned with the nature of reality and the acquisition of knowledge (Solem, 2003). Ontology discusses whether the social world is regarded as something external to social actors or as something that people are in the process of fashioning through their actions and perceptions (Bryman, 2004). Realism and relativism are the two main ontological approaches in research. Realism asserts that realities exist outside the mind and are driven only by immutable, natural laws. The ‘real’ social world exists independently of our perception of it and is essentially objective (Denzin and Lincoln, 2000). In the relativist perspective, on the

other hand, “realities exist in the form of multiple mental constructions” as a product of individual consciousness and are “dependent for their form and content on the person who holds them” (Guba, 1990, p.20).

Epistemology relates to the nature and scope of knowledge. According to Maynard (1994), “epistemology is concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate” (p.10). The two main epistemological approaches which have underpinned research are objectivism and subjectivism. Objectivist epistemology holds that “meaning exists as such apart from the operation of any consciousness” and “there is an objective truth waiting for us to discover it”, whereas in subjectivism “meaning is imposed on the object by the subject” and all knowledge comes from “an interaction between the subject and the object to which meaning is ascribed” (Crotty, 1998, pp.8-9).

Although ontology and epistemology are considered distinct studies, as theory of knowledge typically involve some assumptions about existence and what exists, they have strong similarities and can be seen as complementary disciplines (Solem, 2003). Realism is often taken to imply objectivism and relativism is identified with subjectivism. However, there are also a number of writers in the research literature who reject this view (Crotty, 1998). In the next section it will be shown how different ontological and epistemological positions can be combined to produce the three main research paradigms.

4.1.2. Research paradigms

Kuhn (1970) characterises a paradigm as “an integrated cluster of substantive concepts, variables and problems” with corresponding methodological approaches and research tools. Hence, a paradigm is “a cluster of beliefs and dictates which for scientists in a particular discipline influence what should be studied, how research should be done and how results should be interpreted” (Bryman and Bell, 2007, p.25). A paradigm contains assumptions about the ontological and epistemological nature of the research and translates them into the methodological position of the person conducting research. In the field of business management and social science two main paradigms are dominant, namely positivism and interpretivism. Although the terms positivism and interpretivism

will be used, there are a number of alternative characteristics used as substitutes for these two paradigms in the literature (Table 4.1).

Positivism	Interpretivism
Quantitative	Qualitative
Objectivist	Subjectivist
Scientific	Humanistic
Deductive	Inductive
Experimental	Hermeneutic
Empiricist	Naturalist
Traditionalist	Phenomenological

Table 4.1. Alternative attributes used to describe the main research paradigms
Adapted from: Ticehurst and Veal, 2000 and Mangan et al., 2004

Positivism

The theory of positivism was developed by a French thinker Auguste Comte (1798 – 1857) who outlined features of his philosophical approach in six volumes entitled ‘Course of Positive Philosophy’ published between 1830 and 1842. Underlying positivism is the assumption that the researcher is independent of social reality and neither affects nor is affected by the subject of the research (Bryman, 2004, Remenyi et al., 2005, Bryman and Bell, 2007). Hence, a positivist aims to “explain and predict reality, where reality is considered to be objective, tangible and fragmentable” (Mentzer and Kahn, 1995, p.232).

In the positivist perspective, “research has been conceived as the creation of true, objective knowledge, following a scientific method. From what appears or is presented as data, facts, the unequivocal imprints of ‘reality’, it is possible to acquire a reasonably adequate basis for empirically grounded conclusions and, as a next step, for generalisations and theory building” (Alvesson and Skoldberg, 2000, p.1). Hence, the main focus is on hypothesis testing (Easterby-Smith et al., 2002) and the end product of research should be “the derivation of laws or law-like generalisations analogical to those produced by the physical and natural scientists” (Remenyi et al., 2005, p.32). As a result, “research findings in the positivist tradition are considered value-free, time-free, and context-independent, with the general agreement that casual relationship can be discovered” (Mentzer and Kahn, 1995, p.232).

However, it can be argued that with its commitment to value-neutrality positivism offers only a superficial basis for inquiry in social and business research and important unique qualities of social phenomena could be missed if inquiry were based on categories derived only from an observer's analytic interest (Hall, 1999). By removing much of the context and the generic nature of the research findings, positivism can give only a partial view of phenomena, particularly in the complex, real-world business situations (Naslund, 2002). Hence, many social scientists argue against positivism, emphasising that "physical sciences deal with objects which are outside people whereas social sciences deal with action and behaviour which are generated from within the human mind and that, furthermore, the interrelationship between the investigator and what was being investigated was impossible to separate" (Mangan et al., 2004, p.568). Additionally, while in the physical sciences research can be undertaken in controlled laboratory conditions, in the business world it is much more difficult to isolate a few variables for investigation.

Interpretivism

Interpretivism developed as a result of criticisms of the positivistic philosophical position. The focus of the interpretive approach is on understanding a business or social phenomena rather than on measuring, explaining or predicting it (Mentzer and Kahn, 1995, Bryman and Bell, 2007). The advocates of this position argue that there is a need to focus social inquiry on the meanings and values of actors in order to understand what is happening and why it is happening (Crotty, 1998). The research methods used in interpretative studies seek to "describe, translate and otherwise come to terms with the meaning, not the frequency of certain more or less naturally occurring phenomena in the social world" (Hussey and Hussey, 1997, p.53). The researcher becomes an active part of the research process and considers themselves "interactive, cooperative and lacking a privileged point of observation" (Mentzer and Kahn, 1995, p.232). In contrast to the reductionist⁶ positivist approach, interpretative research offers a holistic perspective on a given problem and allows much more complicated social situations to be studied. This helps the researcher to cope with the complexities of business and management (Remenyi et al., 2005).

⁶ Reductionism assumes that a complex system is nothing but the sum of its parts and an account of it can be reduced to the interactions of its constituents.

However, as “interpretive research findings are considered time- specific, contextual and causality is unattainable” (Mentzer and Kahn, 1995, p.232), often they are criticised by the quantitatively-oriented research world as unscientific, personalised and biased (Naslund, 2002). The main challenges for the interpretative paradigm are in dealing with the complexity of data collection and analysis and maintaining rigour and generalisability (Meredith, 1998).

Each research paradigm has a number of different research methodologies associates with it. A methodology can be defined as “a theory of the method, including its epistemological and ontological assumptions” (Jamal and Hollinshead, 2001, p.67). In other words, a methodology is a way of describing and analysing methods, highlighting their limitations and clarifying their origin, assumptions and consequences. The methodologies associated with positivism and interpretivism are summarised in Table 4.2. Nevertheless it needs to be emphasised that this division is not fixed and some methodologies can be used under both paradigms depending on the assumptions of the researcher (Hussey and Hussey, 1997).

Positivism	Interpretivism
Cross-sectional studies	Action research
Experimental studies	Case studies
Longitudinal studies	Ethnography
Surveys	Feminist perspective ⁷
	Grounded theory ⁸
	Hermeneutics ⁹
	Participative enquiry

Table 4.2. Methodologies associated with the main research paradigms
Source: Hussey and Hussey, 1997

Although positivism and interpretivism are the two dominant paradigms in social science, there are also other approaches adopted in specific research projects. These include: critical realism, critical inquiry, postmodernism, etc. (Crotty, 1998). For the purpose of this thesis, critical realism will be presented in greater detail. This approach provides a ‘middle ground’ between positivism and interpretivism, allowing the researcher to achieve synergy from combining aspects of these two philosophies.

⁷ Feminist perspective focuses on gender issues in social science research.

⁸ Grounded theory is a qualitative research methodology where a theory is generated from data collected in the process of conducting research.

⁹ Hermeneutics involves interpretation theories.

Critical realism

Critical realism, sometimes called post-positivism, can be considered as a ‘bridging’ theory between two extreme viewpoints, positivism and interpretivism (Easterby-Smith et al., 2002). Critical realists accept that we know the world through perceptions, but these perceptions do not define the totality of the world. Bhaskar cited by Mutch (1999) explains this concept: “while social structures are dependent upon the consciousness which the agents who reproduce or transform them have, they are not reducible to this consciousness. Social practices are concept-dependent; but, contrary to the hermeneutical tradition in social science, they are not exhausted by their conceptual aspects. They always have a material dimension” (p.328). Social conditions are “having real consequences whether or not they are observed and labelled by social scientists”, but at the same time “concepts are human constructions” (Easterby-Smith et al., 2002, p.33). Thus, critical realism can “combine together the model of science as social practice of production of knowledge with a realist understanding of knowledge as about something independent of itself”. In other words, the external world is “independent of our knowledge of it“, but, at the same time, it is “knowable and open to change” (Benton and Craib, 2001, pp.57-58). As a result, scientists are capable of discovering and knowing reality but not with certainty. They need to construct various views of this reality in order to comprehend a given phenomena in related time and space (Riege, 2003).

Similarly to positivism, critical realism seeks objectivity in the research process. Nevertheless, while positivists believe that neutrality of the researcher is fully achievable, critical realists acknowledge that their values and beliefs could bias the findings and they apply methods to mitigate this effect (Benton and Craib, 2001). One way of achieving objectivity of research results may be use of different research methods to conduct the study (Meredith, 1998). Thus, critical realism supports the case for “methodological pluralism” as it recognises the value of different approaches for dealing with problematic situations (Easterby-Smith et al., 2002, Solem, 2003).

Table 4.3 summarises the three research paradigms from ontological, epistemological and methodological perspectives. It can be seen that the positivist, interpretivist and critical perspectives and associated methodologies are different in their characteristics. However, they can be used in a complementary fashion, provided that their distinctive features are respected and the strengths and weaknesses of each are recognised (Solem,

2003). What is important here, as Frankel et al. (2005) acknowledge, is not whether the different paradigms are right or wrong but rather that the differences between them exist below the level of awareness of the researcher. As they will influence his / her world-view and the foundations on which they build knowledge, the underlying paradigm needs to be made explicit to understand the limitations and potential of different forms of research and minimise the ambiguity of the research outcomes.

	Ontology	Epistemology	Methodology
Positivism	Realist Reality exists out there and it is driven by immutable, natural laws and mechanisms. Knowledge of these entities, laws and mechanisms is conventionally summarised in the form of time- and context-free generalisations. Some of these generalisations take the form of cause-effect laws.	Objectivist It is both possible and essential for the inquirer to adopt a distant, non-interactive posture. Values and other biasing and confounding factors are thereby automatically excluded from influencing the outcomes.	Experimental / manipulative Questions and/or hypotheses are stated in advance in propositional form and subjected to empirical tests under carefully controlled conditions
Critical Realism	Critical realist Reality exists but can never be fully apprehended. It is driven by natural laws that can only be incompletely understood.	Modified objectivist Objectivity remains a regulatory ideal but can only be approximated.	Modified experimental / manipulative Methods emphasising critical multiplism. Redresses imbalances by doing inquiry in more natural settings, using more qualitative methods and reintroducing discovery into the inquiry process.
Interpretivism	Relativist Realities exist in the form of multiple, mental constructions, socially and experientially based, local and specific, depending on their form, content and the person who holds them.	Subjectivist The inquirer and the inquired are fused into a single (monistic) entity. Findings are the creation of a process of interaction between the two.	Hermeneutic / dialectic Individual constructions are elicited and refined hermeneutically, and are compared and contrasted dialectically- with the aim of grasping the subjective meaning of social action.

Table 4.3. Ontological, epistemological and methodological bases of three lead research paradigms
Adapted from: Guba, 1990

4.1.3. Research paradigms in logistics and supply chain research

Logistics research is dominated by the positivistic tradition (Mentzer and Kahn, 1995, Ellram, 1996, Naslund, 2002, Gammelgaard, 2004, Mangan et al., 2004, Spens and Kovacs, 2006, Kovacs and Spens, 2007). Seaker et al. (1993) suggest that logistics enquiry needs a scientific approach as rigorous theory cannot be built through

qualitatively-derived descriptions of a given phenomena and the relationships between them. Astrup and Halldorsson (2008) note that in the traditional perspective, “logistics is a practice-oriented and solution-based discipline, and has developed under strong influence from physical sciences by making non-living phenomena its study objects. The predominant objects of study relate to tangible artefacts, but to a smaller extent human intervention or influence” (p.3). As a result, social agents operating logistics systems are considered in terms of their functional contribution to the system. Their role is viewed as complying with the logic of the system in order to achieve the key performance objectives and their individual characteristics and objectives are ignored (Aastrup and Halldorsson, 2008). Consequently, the positivist-grounded survey method heavily dominates logistics research, as Mentzer and Kahn (1995) prove based on contributions in the *Journal of Business Logistics* over the period of 1978 – 1993. Sachan and Datta (2005) confirm the strong preference of logistics and supply chain researchers for quantitative approaches, based on a review of all the papers published in the *Journal of Business Logistics*, *International Journal of Physical Distribution & Logistics Management* and *Supply Chain Management: An International Journal* between 1993 and 2003. Interestingly, Naslund (2002) and Larson and Halldorsson (2004) note that the positivistic approach is predominant in the USA, while European researchers make more use of qualitative studies, even though quantitative research dominates in general. However, when choosing a positivist strategy, there is a danger that by focusing on optimising control and generalisability, one can easily compromise the realism of the study thus reducing the scope for practical application (Mentzer and Flint, 1997, Solem, 2003, Golicic et al., 2005).

In response to this criticism, in the last few years new approaches have emerged, bringing logistics closer to a more interpretative paradigm (Ellram, 1996, Halldorsson and Aastrup, 2003, Solem, 2003, Spens and Kovacs, 2006). There has been a number of articles published promoting research methodologies associated with this paradigm, for example case studies (Ellram, 1996, Naslund, 2002), ethnography or action research (Naslund, 2002). Frankel et al. (2005) encourage logisticians to make more intensive use of qualitative methods in order to fill what they call the “white space” of logistics research. The efforts to shift the main focus away from the positivist paradigm have been particularly successful in the Nordic countries. A review conducted by Vafidis (2007) shows a clear shift from quantitative towards qualitative approaches in Finnish and Swedish doctoral research. Quantitative methods were dominant in 56% of doctoral

thesis prepared over the period 1994 – 1998, whereas qualitative approaches dominated in 56% of the dissertations written between 1999 and 2003. The prevalence of qualitative approaches in logistics doctoral research within the Nordic countries between 1990 and 2001 was also shown in an overview compiled by Gubi et al. (2003). Despite the advantages of using the interpretative approach, it is hard to generate objective knowledge using purely qualitative methods (Frankel et al., 2005). Therefore it would be desirable to find a way of balancing the two approaches in order to exploit the synergies of associated methods while minimising their potential weaknesses.

Recently, there has been a move away from the dichotomic choice between the positivist and interpretivist paradigms in logistics and supply chain research. The need for a bridging, real-world philosophical perspective has emerged with the development and maturing of logistics as a field of research (Mangan et al., 2004). Acknowledging the complex nature of the discipline, Aastrup and Halldorsson (2008) disprove the “myth of positivism” by providing a justification for applying critical realism as the main paradigm for logistics case study research. Although research projects directly indicating critical realism as their underlying philosophical assumption are still relatively rare, the application of different viewpoints and approaches within a single research project has become more common in scientific literature on the subject. “All research problems cannot be solved with the same approach or research strategy. Some research problems are better approached by quantitative methods, some by qualitative and some, perhaps, by a combination of both” (Naslund, 2002, p.335). Ellram (1996) states that both qualitative and quantitative approaches to data analysis may be appropriate in most situations and the choice should be dictated by their ability to meet the research objectives. Seaker et al. (1993) and Dunn et al. (1994) argue that the application of a multiple method approach in logistics research can help to combine theory-testing and theory-building in a research project. This approach is known as methodological triangulation (Creswell, 2003, Jack and Raturi, 2006) and will be discussed in more detail in a later section.

New (1997) approaches the problem of underlying methodological assumptions and research purpose from a different perspective. He does not directly suggest any particular methodology but emphasises that the intellectual foundations of the research work need always to be acknowledged and made explicit. He also suggests that the research agenda in logistics and supply chain management should not be driven solely

by the interests of the industry. Otherwise, he warns, research would lose both its intellectual and ethical integrity. It is important that in seeking a real-world perspective, researchers should not forget that their priority is to follow an academic agenda and not simply to satisfy private sector users. Although the practical utility of the research findings is vital in a business-oriented discipline like logistics and devoting time and effort to a development of purely theoretical concepts may not yield uttered benefit, it is necessary to find a balance between advancing the discipline and striving to satisfy industry partners.

Arlbjorn and Haldorsson (2002) discuss the impact of philosophical suppositions on logistics knowledge creation and argue that the latter has three levels: the meta-level, which includes ontology and epistemology, a discipline level and a practice level. Further, they distinguish between the “hard core” and the “protection” belt in the discipline. The hard core focuses upon the flow of materials, information and services along the vertical and horizontal supply chain. The aim is to coordinate the flows based on system thinking. The protection belt is more difficult to define precisely and lies at the interface between logistics and other disciplines, for example human resource management or accountancy. The former should be viewed as a common object of study within the logistics discipline, whereas the latter reflects the heterogeneity of concepts used to explain or understand the hard core. Hence, the protection belt is constantly changing, while the hard core of logistics should be left intact.

With the evolution of logistics as a discipline, the methodological choices of researchers expand to include a broader spectrum of methods and tools helping scientists to explore and understand the complexity of logistics and supply chains in greater depth. In order to conduct a high quality enquiry into sophisticated logistics systems, one must acknowledge the need to reach beyond basic analytical techniques which focus on modelling and cost optimisation and include attitudinal and behavioural aspects of operations (Gammelgaard, 2004, Golicic et al., 2005, Kovacs and Spens, 2005, Craighead et al., 2007, Carter et al., 2008). Hence, the theoretical foundations of the logistics and supply chain management discipline continuously evolve, allowing researchers to view real-world problems from an array of philosophical perspectives, leading to scientific advancements and enrichment of the body of logistics knowledge.

4.1.4. Paradigmatic stance of the thesis

As already emphasised, the intellectual background of the researcher largely determines the way the study is conducted, which data collection and analysis methods are adopted and how the results are interpreted. In a wider context, the ontological and epistemological suppositions will influence the choice of a topic to be studied and help to establish the focus of scientific interest. Due to its nature, along with the preferences of the researcher, this study is grounded in the critical realist paradigm. The challenge of employing critical realism is to adopt multiple perspectives and methods to gain insight into the phenomenon being studied, without compromising the objectivity of the research or over-simplifying the research findings (Easterby-Smith et al., 2002, Solem, 2003, Aastrup and Halldorsson, 2008).

It has been decided in this study that the logistics and supply chain management discipline is too complex to be explored in a strictly quantitative, positivist way. Logistics and distribution systems do not exist in isolation, but they are a part of wider business structures. They are business-context dependent and subject to external pressures from both other supply chain members and the wider economic environment. Further, logistics systems are social creations and the human element cannot be ignored in the course of this research project. The views and experiences of large samples of individuals were collected and analysed using both quantitative as well as qualitative techniques to ensure the maximum ‘realism’ of the research findings. This concept of methodological triangulation, where both qualitative and quantitative methods are applied, has been identified as offering the greatest potential for an in-depth exploration of future developments in the sustainability of road freight transport.

This research consists of three elements: investigation of potential determinants influencing the intensity and direction of key logistics trends, quantification of likely future changes in the key trends and their determinants and, finally, modelling of the results to assess the magnitude of the environmental impact of road freight transport in the UK, in 2020. Therefore, this study is both exploratory and explanatory in nature, what fits well with the critical realist paradigm.

4.2. Research Framework

According to McGrath (1982) the research process is “a series of logically ordered...choices. Those choices run from formulation of the problem, through design

and execution of a study, through analysis of results and their interpretation. The series of choices is locally directional: plan must come before execution; data collection must come before data analysis” (p.71).

Typically, the research process consists of the following steps (Ferber and Verdoorn, 1967, Hussey and Hussey, 1997, Maylor and Blackmon, 2005):

1. Formulation of the problem
2. Development of working hypotheses or research questions
3. Planning the study
4. Data collection and processing
5. Analysis and interpretation
6. Presentation of results

The generic character of this outline allows it to be adapted to any research investigation in any discipline. Mentzer and Kahn (1995) further develop this framework to provide “a comprehensive perspective on the logistics research process” (p.233). Their framework, presented in Figure 4.2, was adopted in designing this research project. The research process was thus divided into three stages:

1. Idea generation and substantive justification

The primary motivation to undertake this research project originates from the author’s educational background in logistics and supply management, previous research into environmental aspects of business activity and personal interest in logistics, sustainability and the environment. The challenging character of the project and particular relevance, practicality and applicability of the expected output were additional incentives to undertake this research. The literature review conducted on the subject of the environmental impact of road freight transport revealed significant gaps in this field. Although measures have been identified to improve the environmental performance of logistics, very little attempt has been made to quantify their likely future effectiveness, particularly on a macro-level scale. An attempt to fill the existing gap in the literature, the initial research idea evolved into a well formulated problem and specific research questions were developed.

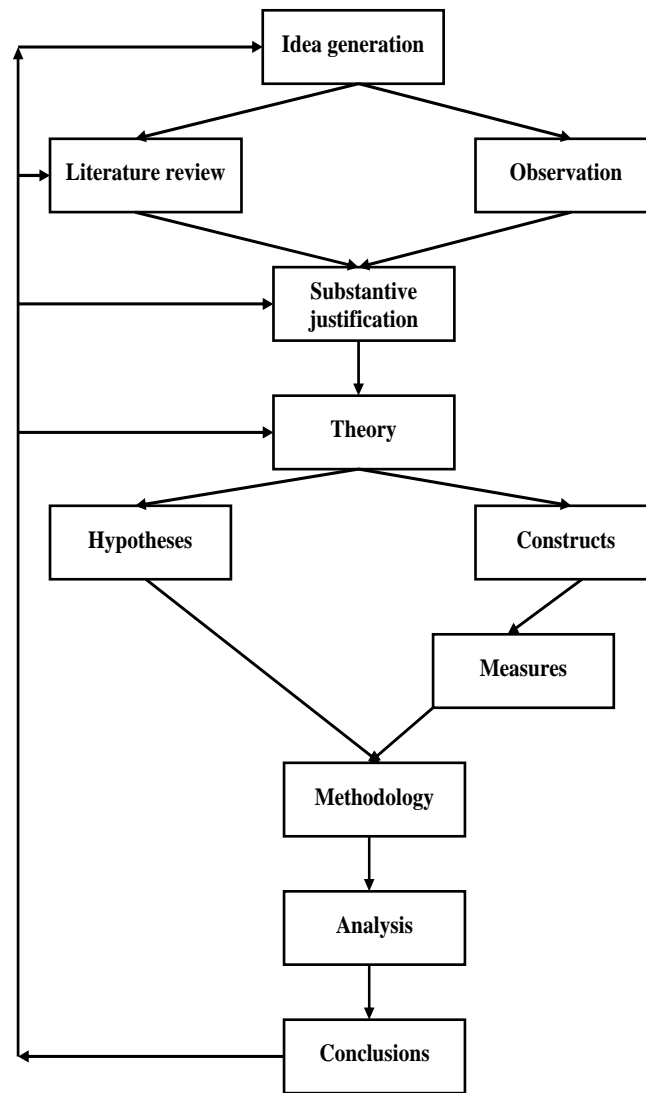


Figure 4.2. A framework of logistics research
Source: Mentzer and Kahn, 1995

2. Theory development and choice of methodology

At this stage, based on the literature review, the theoretical framework for this research was developed. The complex interrelations between different variables determining future environmental impact of road freight transport were mapped in order to structure the research process. This framework was described in Chapter 3. The appropriate research methodology was then selected, including philosophical considerations, as well as a selection of methods and tools to collect and analyse the necessary data.

3. Data collection, analysis, conclusions and directions for future research

The appropriate data was then collected and analysed. The interim findings were disseminated through taking part in conferences and workshops. In this way useful

feedback and comments were obtained and incorporated into the final research findings. The whole process was documented throughout to ensure maximum credibility and traceability. Finally, the last part of the analysis involved summarising the findings of the study and generating ideas for future research.

4.3. Literature Review

The literature review is an essential part of the research process and the research report (Ticehurst and Veal, 2000, Hart, 2003). It helps to identify work already completed or in progress that is relevant to the particular subject area, assess its strengths and weaknesses and prevent the researcher from duplicating what has already been done. It also helps to generate new ideas (Hart, 2001a, Wisker, 2001). Establishing what research has been published in the chosen area supports the research design process by identifying the key approaches, data collection and analysis methods best suited for the topic. It also helps to identify gaps in the existing literature, which can be translated into research questions providing an explicit justification for the research project (Saunders et al., 2007).

The following sources were used to conduct the literature review:

- Heriot-Watt University library
- Online journal databases (Emerald Fulltext, ScienceDirect, EbscoHost, IngentaConnect and JSTOR)
- Conference proceedings and working paper collections
- Internet

The literature review started with a series keyword searches in several academic journal databases and the library catalogue (Burton, 2000). Examples of key words used included: 'green logistics', 'environmental impact of transport', 'CO₂ emissions', 'road freight transport', 'vehicle utilisation' or 'supply chain structure'. This was then expanded by tracing back the reference lists of the articles and books found using the keyword search. Conference proceedings and working papers prove to be a good way of accessing most recent research and work in progress. Additionally, a general internet search was conducted with the same search terms used as in the academic literature search. This search provided an interesting broadening of the area as additional information from government, public agencies, trade bodies, commercial organisations etc. was found.

Although the main focus of the review was on literature relevant to the specific topics being investigated, additional searches were carried out to identify the methodological approaches to be adopted. Reviewing methodological publications supported the research design process and selection of data collection techniques.

4.4. Methodological Triangulation

As already noted, the challenge of research based on the critical realism paradigm lies in adapting multiple methods to investigate a given research problem. Such an approach is known as triangulation. Hussey and Hussey (1997) define triangulation as the use of multiple research approaches, methods and techniques in the same study. The main objective of triangulating research is to “overcome the potential bias and sterility of a single-method approach” (p.73), which should lead to greater validity and reliability of findings. Triangulation gets its name from the land surveying method of fixing the position of an object by measuring it from two different positions (Ticehurst and Veal, 2000).

Following Easterby-Smith et al. (2002), there are four distinct types of triangulation:

- **Data triangulation**, where data is collected from different sources or over different time frames.
- **Investigator triangulation**, where different people independently collect data on the same situation.
- **Theoretical triangulation**, where models or theories from one discipline are used to explain a phenomenon in another discipline.
- **Methodological triangulation**, where both quantitative as well as qualitative research methods are employed.

Jack and Raturi (2006), describe three main reasons for using methodological triangulation:

- **Completeness**- quantitative and qualitative methods complement each other, providing a level of investigative detail that would not be possible by using one method alone.
- **Contingency**- this is driven by the need for insights into why and how a particular strategy is chosen. For example qualitative inquiry may be used to investigate the nature of the attributes of a phenomenon before an attempt is made to quantify or measure such attributes.

- **Confirmation-** using both types of research methods should enhance the ability of a researcher to draw conclusions from their studies and improve the robustness and generalisability of the findings.

There are also a few potential disadvantages of mixed- method approaches that should be considered in planning the research (Maylor and Blackmon, 2005):

- They are more time and resource-consuming
- Possible difficulties can arise in reconciling the answers from different methods
- Different methods may not produce additional information
- Only a specific method or a narrow set of methods may be considered appropriate in a given research area
- Different methods may reflect different and incompatible research approaches

Despite these potential flaws, the concept of triangulation has gained considerable support and endorsement amongst logistics and supply chain experts. According to New and Payne (1995), “the mechanism of academia offers a trade-off: one can pursue artificial and abstract problems with the rigour necessary to play the research game, or one can pursue more interesting and real issues and be lost in the extraordinary complexity and ambiguity of the real world” (p.62). The authors, nevertheless, suggest that employing different investigation methods helps to cover the wide scope of the logistics discipline and improve chances of generating relevant and applicable research. Such triangulated approach to logistics research and the use of multiple quantitative and qualitative methods has also been suggested by numerous authors (Seaker et al., 1993, Naslund, 2002, Mangan et al., 2004, Craighead et al., 2007, Carter et al., 2008). Mangan et al. (2004) conclude that “the trend in management research generally is increasingly to use methods and approaches which provide a middle ground between contrasting positivist and phenomenological paradigms and perspectives” (p.565). Craighead et al. (2007) argue that methodological triangulation may be particularly beneficial in logistics as it strengthens research results and helps the discipline to become fully mature. According to Solem (2003), “logistics as knowledge has its sources from different scientific disciplines and represents, by nature, an interdisciplinary area, meaning methodological pluralism” (p.452). Similarly, Dunn et al. (1994) and Mentzer and Flint (1997) advocate methodological triangulation as a means of researching the true nature of the logistics phenomenon and the supply chain management reality. Naslund (2002) and Mangan et al. (2004) argue that the use of both qualitative and

quantitative methods is necessary to advance logistics research and to gain a “real-world” perspective on the subject.

In this project two types of triangulation are used. Firstly, data triangulation was applied. The data was collected from participants representing different types of supply chain members (for example manufacturers, customers, logistics service providers, enablers, etc.) and different industries (like retail, primary, consultancy, information technology, etc.). This was done in order to obtain a more objective and unbiased views on the future of road freight transport. It has also permitted comparison of the opinions of different groups involved in shaping this future and identified the areas that may be subject to conflicting pressures. The detailed classification of participants taking part in the research will be presented in the relevant chapters. The data triangulation involves also combining secondary data from published official statistics, reports etc. with primary data collected for the purpose of this research.

Additionally, methodological triangulation was applied. Qualitative and quantitative methods were utilised to serve the exploratory and explanatory purposes of this research. The research methods applied in this study are focus groups, Delphi survey and spreadsheet modelling. Focus groups are principally qualitative in nature, while spreadsheet modelling is a quantitative technique. The Delphi method tends to be classified as qualitative. However, for the purpose of this project it was combined with a survey approach to support the quantification of future changes in the key logistics parameters. Therefore, the statistical analysis of survey results was possible.

4.5. Research Methods

As was noted above, a research method is a particular means of approaching a research question. A method is concerned with pragmatic issues relating to particular practices and techniques which are applied in the process of research (Crotty, 1998, Ticehurst and Veal, 2000). Hence, the methods selected to conduct research should be guided by, and grounded within, a particular methodology (Easterby-Smith et al., 2002). Similarly to methodology, research methods can be classified as qualitative or quantitative (Figure 4.3), although this division is not definitive (for example interviews and case studies can be designed to collect quantitative or qualitative data, etc.). The methods chosen to conduct this research are presented and justified below.

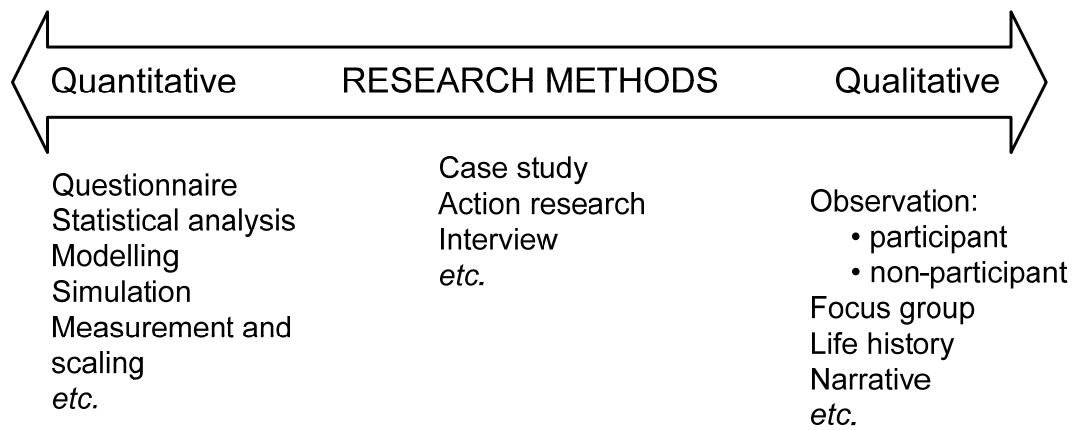


Figure 4.3: Quantitative and qualitative research methods
 Adapted from: Hussey and Hussey, 1997, Crotty, 1998, and Maylor and Blackmon, 2005

4.5.1. Focus group approach

The focus group method is a form of a group interview with a number of participants selected and invited to discuss the topic of which they have personal experience or specific knowledge (Krueger, 1994, Patton, 2002, Bryman, 2004, Bryman and Bell, 2007). Focus groups are distinguished from group interviews in three ways (Bryman, 2004, Barbour, 2007, Bryman and Bell, 2007):

- Focus groups tend to emphasise a specific topic that is explored in depth, whereas group interviews often span a range of subjects.
- In the focus group method the interest of a researcher is on both what is discussed and how it is discussed (the interactions between participants as members of a group). In group interviews the main focus is on the opinions of individuals not the interactions between them.
- The group interview technique is sometimes used to save resources by collecting opinions of a number of individuals simultaneously. This is not a reason to carry out focus groups.

The process of conducting a focus group study consists of three phases (Morgan, 1988, 1993, Carey, 1994, Krueger, 1994): planning the study, conducting the research, followed by analysis and reporting. At the planning stage the following issues need to be agreed upon and/or organised: purpose of the study, planning and timetable, number of groups, number of participants per group and recruiting the participants (Morgan, 1993, Krueger, 1994). Planning should begin by reflecting on the purpose of the study and deciding if focus groups are the right method to meet the research objectives. In general, focus groups are useful to gain insights in exploratory or preliminary studies where the researcher wants ideas to emerge from the group or they need additional

information to prepare for a large-scale study. They are also suitable where there is a communication or understanding gap between groups or categories of people or the purpose is to uncover factors relating to complex behaviour or motivation. However, focus groups should not be applied where statistical projections are needed, the study concerns emotionally-involving or very controversial topics or there is a need to ensure the confidentiality of sensitive information (Krueger, 1994).

The choice of time and location can have a strong influence on the level of attendance at focus groups (Greenbaum, 1998). The periods when the potential participants are likely to be heavily occupied with their professional commitments should be avoided if possible, for instance pre-Christmas months if participants from the logistics industry are recruited. Choosing a venue in the proximity of a usual workplace of invitees, with good communication links can aid turnout as well.

The number of discussions is one of the first planning issues. The number of groups should be determined mainly by the research goals, the exploratory or confirmatory nature of the study, number of different population sub-groups required and geographical dispersion of participants (Morgan, 1988). Typically, however, the discussions reach saturation level after three or four groups, i.e. additional discussions produce few new ideas. In the logistics-related studies identified in Table 4.4 the number of focus groups ranged between one and thirteen.

Focus groups typically involve between six and twelve participants (Krueger, 1994, Patton, 2002, Barbour, 2007). The effect of group size on the degree of a moderator's control over the discussion and quality of data collected is shown in Figure 4.4. The data quality and controllability are optimal in groups of six to ten participants. The focus group should comprise people with similar background expertise but with sufficient variation among participants to allow for contrasting opinions (Carey, 1994, Krueger, 1994). If the participants' views are too unanimous, the discussion will not be sufficiently holistic, open and innovative. However, if they are too different in their opinions and perceptions, the discussion is likely to be counterproductive and difficult to control.

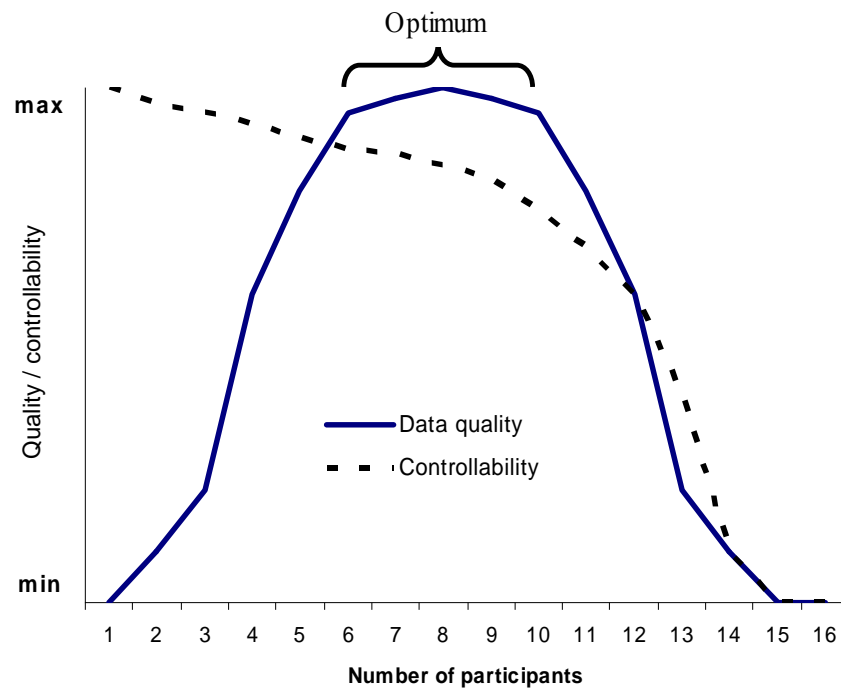


Figure 4.4. Effect of focus group size on quality and controllability
Source: Sanchez Rodriguez et al. 2010

Recruiting the right participants is crucial to the overall success of focus group research and it is one of the most important elements in the planning process (Morgan et al., 1998). Firstly, the researcher needs to define the target population and segments within it. Then the appropriate composition for each group should be established and potential invitees screened for agreed eligibility and exclusion criteria. Invitations to the focus group sessions should be personalised so that each participants feels that they are needed at the discussion and their insight into the subject would be of value to the researcher. The invitation letter should stress that the potential participant has certain characteristics or special expertise related to the subject under investigation. The invitation letter should be followed up by the phone contact to ensure attendance. An information pack containing additional information about the session, location and topic of discussion should be also sent to invitees before the meeting (Krueger, 1994, Morgan et al., 1998).

The conducting stage consists of moderating the group discussions. In this phase the following issues should be given consideration: moderator's approach, methods of data recording, venue layout and equipment used.

A moderator or facilitator is a person who runs the focus group session. Typically, they will be expected to guide the discussion by asking questions or getting participants to comment on certain issues but they should not be too intrusive (Bryman and Bell, 2007). Krueger (1994) recommends that more than one person conduct focus groups so that a moderator can focus on facilitating the discussion while others take detailed notes, record the session, etc. The notes taken at the event aid the analysis and help to identify the points raised by each participant, for example for inter-group comparisons. Further, using different moderators during the sessions increases the reliability of results (Bryman and Bell, 2007).

The level of moderator involvement is a function of the desired format of the group sessions. A structured approach provides the participants with a number of issues to be considered and the facilitator actively controls the development and dynamics of the debate to keep the discussion on the desired track. In the unstructured approach participants are asked some prompting questions to start a free discussion between them and the interventions of the moderator are kept to a minimum (Morgan, 1993). The evidence from Table 4.4 suggests that in logistics-related focus group research, an unstructured approach is more popular for exploratory studies and a structured approach for explanatory studies.

Venue layout and equipment are other important factors in conducting a focus group session. The venue layout must ensure that all the participants are able to listen to the facilitator and their fellow participants and they can easily see the presentation and other materials used to support the facilitation (Sanchez Rodrigues et al., 2010).

Finally, after the conducting stage is completed, the data needs to be analysed, summarised and a final report written up. Most of the authors recommend recording and transcription of the focus group sessions (Ticehurst and Veal, 2000, Bryman, 2004, Bryman and Bell, 2007). When using transcripts, the researcher needs to be mindful of the group setting, the non-verbal data, changes and discrepancies in a member's contributions. This can be done by incorporating data from the notes (Carey, 1994). If possible, it is advisable for another person to analyse at least part of the data independently. The results can be then compared for consistency of interpretation (Ticehurst and Veal, 2000).

Krueger (1994) recommends considering the following while analysing focus group data:

- **Words** – the actual words used by participants and their meaning. A variety of words and phrases will be used and the researcher needs to assess the degree of similarity among them.
- **Context** – some of the responses may be triggered by a certain stimulus, for instance as a reaction to another participant's statement. Incorporating the context into the analysis helps to discover a full meaning of the comments made.
- **Internal consistency** – participants may change their positions as the discussion develops. Tracing the causes of this change may provide a valuable input into the study.
- **Frequency and extensiveness of comments** – some themes are discussed by more participants (extensiveness) and some comments are made more often (frequency) than others. The topics raised more frequently and / or discussed more extensively are likely to be more important and relevant.
- **Intensity of comments** – another denominator of the importance of a given topic is the intensity with which participants talk about it. Intensity may be difficult to spot with transcripts so any non-verbal indicators should be noted at the event.

While analysing focus group data it is also important to test for theory saturation to ensure that the findings are as complete as possible. After that, the final report should be prepared, targeted to the audience and appropriate for the purpose of the study (Krueger, 1994).

Strengths and weaknesses of focus group research

The focus group method, like every other research technique, has its strengths and weaknesses. The researcher should be aware of potential advantages and drawbacks to be able to identify cases in which focus groups are to be preferred and in which they should be avoided. Advantages of the method include:

- The researcher has a high degree of flexibility in conducting the research. They can react to participants' responses and explore unanticipated issues (Krueger, 1994).
- Interaction between participants and more natural research setting enhances data quality (Morgan, 1988, Krueger, 1994, Patton, 2002).

- The discussions are formed by small groups that can represent big population. However, any generalisations should be made with caution (Krueger, 1994).
- Data collection is relatively cost-effective (Krueger, 1994, Greenbaum, 1998, Patton, 2002).
- The extent to which there is a relatively consistent, shared view or great diversity of opinions can be quickly assessed (Patton, 2002).

Additionally, focus group discussions can shed light on the process of participants' reasoning. Contributors can not only express their views on a given issue but also explain why they hold particular opinions. This allows for an in-depth exploration of the research subject.

The focus group technique has also certain limitations that need to be taken into account:

- The researcher has limited level of control over the data that is generated (Morgan, 1988, Krueger, 1994, Bryman, 2004, Bryman and Bell, 2007).
- The divergent views of some participants can be inhibited by the dominant views from the rest of the group. There is also a risk that the discussion will be dominated by forceful characters with strongly held views (Carey, 1994, Krueger, 1994, Patton, 2002, Bryman, 2004, Bryman and Bell, 2007).
- The number of issues that can be discussed is restricted and the available response time for any particular individual is restricted by the need to involve everyone (Patton, 2002).
- Data can be difficult to analyse as comments must be interpreted within the context of group interaction (Krueger, 1994, Bryman, 2004, Bryman and Bell, 2007).
- Facilitating and conducting focus groups require flexibility and certain skills to manage group interaction (Patton, 2002).
- The technique 'is beneficial for identification of major themes but not so much for the micro-analysis of subtle differences' (Krueger, 1994, p.10)
- Research may require significant resources if cost of travel, room hire, refreshments and transcription, etc. are to be covered (Barbour, 2007).
- Analysis can be time consuming (Bryman, 2004, Barbour, 2007, Bryman and Bell, 2007).

The scene setting can be also bias the participants' opinion. In facilitating the discussion, the moderator presents external information which inevitably introduces some bias or conditioning. Hence, efforts should be made to present any supporting materials in possibly objective and neutral way.

Focus group method in logistics and supply chain research

Focus group discussions are a long established research method in many areas like marketing, business or social studies (Krueger, 1994, Greenbaum, 1998, Bryman and Bell, 2007). Within social science, the earliest published work is from mid 1940s and is based on the application of focus groups 'to examine the persuasiveness of wartime propaganda' by Robert Merton and his colleagues (Morgan, 1988, Barbour, 2007). However, focus groups are still a relatively rarely used approach in logistics research (New and Payne, 1995, Larson and Halldorsson, 2004, Mangan et al., 2004, Frankel et al., 2005). Although not widely applied, focus group interviews are a valued method of gaining insight into practitioners' experience. Previous applications in logistics and supply chain research include trials to define, explore and understand interorganisational relationships, partnerships and alliances in supply chains (New and Payne, 1995, Carter, 2000, Christopher and Juttner, 2000, Dainty et al., 2001a,b, Golicic et al., 2003, Rinehart et al., 2004), assessment and improvement of the IT applications in logistics (Rae-Smith and Ellinger, 2002, Evangelista and Sweeney, 2006) or designing a logistics service quality scale (Mentzer et al., 1999).

Within the logistics and supply chain management area, the focus group method is seldom used as a stand-alone research approach, mostly due to difficulties in generalising the research findings. It is usually considered to be a complementary mean of confirming and getting deeper understanding of survey results (New and Payne, 1995). Focus groups are also frequently used to support the survey design process and to test the suitability and comprehensibility of a wider-scale questionnaire (Sink et al., 1996, Mentzer et al., 1999, Carter, 2000, Evangelista and Sweeney, 2006). When used as the main research method the findings are contingent upon the conditions and context in which the participating businesses operate (Christopher and Juttner, 2000) and additional empirical verification of results is necessary to generalise the results to the whole population (Golicic et al., 2003).

Sanchez Rodriguez et al. (2010) categorise the roles of the focus group within a logistics / supply chain- related research projects into the following categories:

- **Descriptive** – focus group method is used to examine the current state of a certain issue and/or to define future research directions (for instance Holweg and Miemczyk, 2002).
- **Exploratory** – focus groups are used to investigate a particular issue where expert views and empirical experiences are needed. This is further divided into three sub-categories where focus groups are used as a sole research method, in the design of a wider scale survey or to provide input to inform / influence other research methods.
- **Explanatory** – focus groups are used to provide more depth and/or evaluate the reliability and credibility of research findings obtained through other methods, most commonly survey results.

Table 4.4 summarises the different applications of focus groups in logistics and supply chain management research.

Author	Research Approach	Role of Focus Group	Design	Conducting	Analysis
Descriptive					
Holweg and Miemczyk (2002)	Focus group → Process map → Survey → Modelling	To obtain background data on the supply chain and propose future state scenarios	Involved research sponsors but no other information provided	No information provided	No information provided
Exploratory – sole method					
Mangan and Christopher (2005)	Literature Review → Focus Group and Survey	Obtain the views of students of an executive education course on management skills.	1 focus group of 10 students from a Masters course run by authors.	No information provided	No information provided.
Cullen and Webster (2007)	Literature Review → Focus Group	To determine the mechanisms used for the sale and purchase of products, and the role of e-commerce in these.	4 focus groups planned but only 3 carried out. Made up of 4 to 6 postgraduate students and individuals known to the researchers, selected by purposive sampling.	Round table, structured discussion	Identified clusters of topics and also coding of results. Theory saturation tested.
Manuj and Mentzer (2008)	Focus groups and interviews	To identify elements of risk in global supply chains and how they are mitigated	One focus group with seven executives from a global manufacturing firm	No information provided	No, although theory saturation testing with the interviews

Author	Research Approach	Role of Focus Group	Design	Conducting	Analysis
Exploratory – construct development					
Sink et al. (1996) and Sink and Langley (1997)	Literature Review → Focus Group → Survey	Refined a comprehensive literature review undertaken on the 3PL theory. Also, it fed into the design process of a wider-scale questionnaire-based survey.	1 focus group of 11 members representing a broad base of industry. Some selection criteria.	Semi-structured discussion.	Identified clusters of issues.
Mentzer et al. (1997) and Mentzer et al. (1999)	Literature Review → Focus Group → Survey	Helped the researchers to understand the logistics service quality needs of the Defence Logistics Agency's customers. The focus groups findings supported the research team in refining a questionnaire.	13 focus groups with a broad base of opinions. All participants customers of the DLA.	Unstructured.	Identified clusters of topics and also coding of results. Also researcher triangulation.
Dinwoodie (2001)	Focus Group → Survey	Explored students' motivations to study a MSc degree programme	Number of focus groups not given but they involved enrolled students	No information provided	No information provided
Lancioni et al. (2001)	Focus Group → Survey	Identified a list of barriers to development of logistics programmes	4 focus groups of 5-6 staff members from Business Schools	No information provided	List of barriers produced and duplications removed
Golicic et al. (2003)	Literature Review → Focus Group → Survey	Applied to explore and understand inter-organisational relationships	2 focus groups, with 5 and 9 participants. Covered 7 industrial sectors.	Unstructured.	Coding of results and researcher triangulation.
Guinipero et al. (2005)	Focus Group → Survey	Gain information on trends, skill, knowledge and training for supply chain managers	4 focus groups across the US. Participants invited from Fortune 1000 companies. 58 executives from 41 companies attended	Unstructured.	Identified clusters of issues.
Evangelista and Sweeney (2006)	Focus Group → Survey	To verify completeness of the survey instrument and obtain further engagement in research	2 focus groups in Milan and Rome with total of 20 participants from industry and academia	Structured, based around draft survey instrument	No information provided
Tian et al (2008)	Literature Review → Focus Group → Survey	To confirm that the survey instrument was complete and understandable	1 focus group involving 3 managers from 2 manufacturing firms	Structured, based around draft survey instrument	No information provided

Author	Research Approach	Role of Focus Group	Design	Conducting	Analysis
Exploratory - other					
Christopher and Juttner (2000)	Focus Group → Case studies	Gain insights into current practice on managing supply chain relationships	12 focus groups arranged at a conference. Open invitation to conference delegates.	No information provided.	No information provided.
Rae-Smith and Ellinger (2002)	Action research → Focus Group	Applied to evaluate the extent an online logistics system (implemented through action research) was helping to improve customer service.	1 focus group for employees of the company involved in the action research	Structured.	No information provided.
Explanatory – survey results					
New and Payne (1995)	Survey → Focus Group	Applied to validate results of a survey (2.5% response rate) regarding supply chain integration in logistics.	7 focus groups across the UK. 51 participants from a range of industries with group sizes from 3 to 13. Invites sent to personal contacts of research team.	Organised as a dinner party with food and then an unstructured discussion.	Identified clusters of issues.
Rinehart et al. (2004)	Literature Review → Survey → Focus Group	Conducted in order to determine appropriate descriptive terms for each cluster identified in the survey.	3 focus groups of executive MBA students and company executives, all involved in relationship management. 75 participants in total.	Structured, with a range of descriptive terms provided for delegates to select from.	Ranking of the descriptive terms for each cluster based on frequency of selection.
Juttner (2005)	Survey → Focus Group	Provide more depth and insights to survey findings especially as the survey had an 8% response rate	6 focus groups arranged at a conference. Open invitation to conference delegates. Each focus group had 7 to 8 participants.	Structured.	Identified clusters of issues.
Bernon and Cullen (2007)	Case studies → Survey → Focus Group	Compare case study and survey findings with participants' experiences in reverse logistics.	1 focus group with 6 sectors represented.	No information provided.	No information provided.
Explanatory – other opinion based methods					
Dainty et al. (2001a,b)	Interviews → Focus Group	Refine a set of change requirements for improving supply chain integration, obtained through the interviews	3 focus groups across the UK. Composed of smaller construction sector companies and interviewees.	Semi-structured and facilitated by the research team.	Data analysed using NVIVO software.
Blackhurst et al. (2005)	Case studies → Interviews → Focus Group	To identify examples of supply chain disruptions to verify earlier findings	3 focus groups of between 10 and 14 participants from a number of industry sectors.	Structured.	Identified clusters of issues.

Author	Research Approach	Role of Focus Group	Design	Conducting	Analysis
Juttner et al. (2007)	Literature Review → Workshop → Focus Group	Verification and improvement of framework developed in workshop	1 focus group of 14 participants representing a range of industries.	No information provided.	No information provided.
Melnyk et al. (2009)	Literature Review → Delphi Study → Focus Group	Discuss and refine the findings from the Delphi study	1 focus group of 25 participants drawn from the Delphi study respondents	Semi-structured with a clustering exercise.	Identified clusters of issues.

Table 4.4. Summary of articles using the focus group method in logistics
Source: Sanchez Rodrigues et al., 2010

Application of the focus group method in the present study

As noted in the previous section, one of the most common uses of focus groups is in the initial stages of research projects in order to develop or validate concepts for further investigation. The literature strongly emphasises the fact that focus groups should not be used where quantitative data needs to be collected (Greenbaum, 1998). Nevertheless, they can generate hypotheses that merit further quantitative investigation (Kreuger, 1994). For instance, focus groups are often used to inform the design of survey questionnaires (Barbour, 2007). This was the main reason for incorporating focus group discussions into this study.

The main objective of the focus group research was to gain an industry perspective from a diverse range of logistics specialists on the factors that are influencing the key logistics variables and environmental performance of road freight transport. The combined confirmatory - exploratory approach was adapted to seek in-depth understanding of the complex reality of logistics and supply chain management and to confirm the accuracy of factors identified in the literature review. The fast - changing market environment results in current concepts and business models becoming rapidly obsolete and being replaced by new ones. Hence, it was necessary to ensure that the findings from the literature review are still applicable to current logistics practices and to investigate any new factors that might have gained importance recently. As a result a satisfactory balance of theory and practice has been achieved.

The focus group discussions identified a series of possible changes in key logistics parameters. However, given the number and range of specialists participating in the focus group discussions, it was not possible to generalise for the total population of the UK logistics-related businesses. The sessions were also not designed to quantify the projected trends. They have only provided an indication of where the trends will head. The next step of the research was to construct and conduct a Delphi survey to verify and quantify the trends identified by the supply chain experts.

The details of the focus group research process, analysis and findings are presented in the next Chapter.

4.5.2. The Delphi method

The Delphi method is a popular forecasting technique that can be applied to a wide range of research problems and disciplines. Combined with a scenario building approach, it is widely used in mid- and long-term forecasting. This section outlines the characteristics of the method and compares it with other forecasting techniques.

Different approaches to forecasting

Saaty and Boone (1990) list four approaches to forecasting: extrapolating past trends, analysing historical relationships and analogies, constructing future scenarios along with developing trajectories and building a consensus of expert opinion. In the UK detailed road freight statistics have been compiled and published since the early 1970s, permitting the extrapolation of freight trends over differing time-scales. However, in order to construct a forecast by extrapolation, the researcher needs to be confident that the past time-series data contains all the information necessary to forecast future changes in that variable, and that past trends will endure at least during the forecasting period (Helms et al., 2000, Martino, 2003). For example, Adams (1981) challenged the credibility of forecasting based on extrapolation by constructing an absurd scenario for the year 2212. In most cases, the past trends cannot continue indefinitely and it can be very difficult to predict the moment at which a reversal of a trend will occur. As discussed in Chapter 3, traditionally, road traffic models assumed a linear relationship between GDP and road tonne-kms. Thus, forecasts of road freight transport relied heavily on the extrapolation of past trends in GDP and the close correlation between these parameters (McKinnon and Woodburn, 1996). However, firstly the forecasting based solely on the relationship between GDP and road tonne-kms has not been rooted in an understanding of the causes of freight traffic growth. Further, the recent discontinuities in the statistical trends in the key freight parameters in the UK, such as average length of haul, empty running and the ratio of GDP to tonne-kms, since the late 1990s have rendered extrapolation inappropriate.

Forecasting by historical analogy involves an analysis of how systems or people behaved in similar situations in the past (Martino, 1975, Saaty and Boone, 1990, Green and Armstrong, 2007). It is very doubtful that past circumstances will be repeated over the next ten years as companies are likely to come under increasing pressure, among other things, to decarbonise their operations.

According to Ellram (1996), prediction can be served by both quantitative and qualitative methods, depending on the nature of the prediction desired. Quantitative techniques provide better statistical predictability, whereas qualitative data can be used to describe a phenomenon or predict factors influencing it. As the main objective of this research is to construct a baseline BAU scenario of freight transport futures, forecasting based on expert opinion has been identified as the most appropriate of the four approaches. It has the major advantage of rooting the forecasts in a detailed understanding of the underlying causes of freight traffic growth and its carbon intensity. Focus group discussions and Delphi questionnaire surveys were chosen as formal means of capturing and consolidating expert judgment. In order to increase the reliability of the forecast a large panel of experts has been consulted. A structured questionnaire has been used to enable statistical analysis of responses.

Further, the Delphi method was combined with a scenario-building approach, i.e. the outcome of the Delphi survey was used to create a number of future scenarios of developments in road freight transport systems. These scenarios were developed on the basis of an analysis of experts' responses and differences in opinion. The advantage of using scenarios is that this method assesses possible futures for the variable being considered and attempts to determine their likely consequences (Firth, 1977). This is particularly important in medium- and long-term projections, where there is usually a great degree of uncertainty particularly in the future course of external or less controllable factors. Alternative scenarios help to encompass such factors and incorporate them into the forecast (Granger, 1989, Evans, 2003). Another benefit of scenario building is that it takes account of the interrelationship between the variables. A real-world expert outlook on future developments in logistics and supply chain trends and analysis of their underlying causes are used to maximise the credibility and accuracy of the forecast produced in this thesis. The Delphi survey plays a central role in the integrated, multi-phase research design that has been adopted to investigate the key determinants of the future trend in CO₂ emissions from road freight transport.

Development of the Delphi method

The name of the method derives from the Oracle of Delphi. Ancient Greeks believed that the oracle could foresee future events and consulted her on everything from major undertakings, like wars or new urban developments, to personal affairs. Hence, the term Delphi was first applied as a joke but the name stuck (Turoff and Hiltz, 1996). Although

development of the method is commonly attributed to Olaf Helmer and Norman Dalkey from the RAND Corporation (Turoff and Hiltz, 1996), Woudenberg (1991) mentions the first experiment using the Delphi method performed in 1948 to improve “betting scores at horse races”. In the 1950s the Delphi method was used by the RAND corporation as a means of expert-supported military decision-making, particularly with reference to planning and developing new technology (Rieger, 1986, McKinnon and Forster, 2000, Loo, 2002). Since then the Delphi technique has been widely recognised as a means of supporting decision-making processes through the development of more reliable forecasts (Landeta, 2006). It has been applied across disciplines and extensively used in planning and policy-making, long- range forecasting and decision support in both private and public sectors.

At the beginning, as a consequence of their military nature, the first results of Delphi experiments were confidential. In the 1950s and 1960s, the technique was predominantly used for qualitative forecasting, predicting dates and estimating unknown parameters. In the next decade, stress was put on the educational and communicational possibilities of the method. Different forms of the method have been developed, including policy Delphi, decision Delphi or Delphi to estimate unknown parameters (Woudenberg, 1991). Similar classification is proposed by Van Dijk (1990), while Strauss and Zeigler (1975) categorise Delphi studies as numeric, policy or historic.

Over the past century the applications of the Delphi method have also broadened and numerous theoretical methodological reviews as well as practical application studies have been published. Gupta and Clarke (1996) in their bibliographic study report 463 Delphi-related articles published between 1975 and 1994. They also have identified the main domains of Delphi technique applications, which include education, business and management, health care, social science, engineering and many more (Gupta and Clarke, 1996). Landeta (2006) continued this search by reviewing papers published in four main scientific databases between 1995 and 2000 and identified 2247 Delphi-related articles. The Delphi method is also a popular means of doctoral research. Rieger (1986) notes that there were 660 doctoral Delphi-related dissertations listed in the Dissertation Abstracts database between 1970 and 1984 with applications to education, health care, business and industry, public administration or dissertations dealing with an investigation of the technique. According to Landeta (2006), the Delphi method was

employed in 1227 doctoral dissertations listed in ProQuest Dissertations and Theses database between 1985 and 2004.

Characteristics of the Delphi method

A Delphi technique is a systematic, iterative procedure for “structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem” (Linstone and Turoff, 2002, p.3). The Delphi survey usually involves sending a first-round questionnaire to a number of respondents, collating and analysing the data and then re-circulating the questionnaire accompanied by a summary of results. The experts are asked to confirm or modify their previous responses. This procedure is repeated for a pre-determined number of rounds or until a desired degree of consensus has been reached or response rates dwindle (Rowe and Wright, 1999, Hasson et al., 2000, Linstone and Turoff, 2002, Mullen, 2003, Okoli and Pawlowski, 2004, Hsu and Sandford, 2007).

The three main characteristics of the Delphi method are as follows (Woudenberg, 1991, Gupta and Clarke, 1996, Rowe and Wright, 1999, Linstone and Turoff, 2002, Loo, 2002, Landeta, 2006):

- **Anonymity of participants** – typically experts are approached by mail or computer and they remain anonymous to the other members of the panel. The anonymity of participants eliminates the problems associated with group decision making whilst still offering the benefit of providing aggregate judgement of a group of experts that is considered more accurate than the judgement of an individual.
- **Iteration** – there are several rounds of knowledge elicitation and narrowing of the initial range of opinion.
- **Feedback** – in the second or subsequent round, the results of the whole group on the previous round are analysed and fed back to the experts in a statistical format. The statistical aggregation of group response between iterations or for final presentations of study results is considered so important by some authors, that it is sometimes listed as the fourth main feature of the Delphi technique (for instance Rowe and Wright, 1999, Landeta, 2006).

It is recommended to use the Delphi method when the following circumstances occur:

- The problem cannot be solved by application of precise analytical techniques but “can benefit from subjective judgement on a collective basis” (Linstone and Turoff, 2002, p.4)
- The method is particularly appropriate when there is no historical / economic /technical data (Gupta and Clarke, 1996, Rowe and Wright, 1999) or when changes between variables are intuitively expected (Tapio, 2002a).
- When opinion is sought on a topic that has many interpretations and it is hard to formalise in mathematical models (Tapio, 2002a, b)
- The number of individuals involved is too large to “effectively interact in a face-to-face exchange” (Linstone and Turoff, 2002).
- The experts needed to take part in the study come from diverse backgrounds and are not normally in direct communication (Linstone and Turoff, 2002).

The main advantages of the Delphi method are:

- It “relies on a structured, yet indirect, approach to quickly and efficiently elicit responses relating to group learning and forecasting from experts who bring knowledge, authority, and insight to the problem, while simultaneously promoting learning among panel members” (Gupta and Clarke, 1996, p.186).
- It is flexible and can be applied in many research areas (Gupta and Clarke, 1996, Akins et al., 2005, Blind, 2008).
- The wide range of interrelated variables and multidimensional attributes common to most complex research problems can be captured and investigated (Gupta and Clarke, 1996, Akins et al., 2005).
- It offers the benefits of group decision making whilst avoiding the pitfalls of face-to-face interaction, for instance group conflict or individual dominance (Gupta and Clarke, 1996, Akins et al., 2005).
- “Controlled feedback and anonymity through planned, rather than reactionary, responses from experts help panellists to revise their views without publicly admitting that they have done so, thus encouraging them to take up a more personal viewpoint rather than a cautious institutional position” (Gupta and Clarke, 1996, p.186).
- The study can be conducted in geographically dispersed locations without physically bringing the respondents together (Akins et al., 2005).

- The Delphi method enjoys high acceptance in academic, business and government circles if it is performed competently (Blind, 2008).

Conversely, the common weaknesses associated with the Delphi technique are as follows:

- It tends to be time consuming, involves numerous experts and can be rather costly (Landeta, 2006, Hsu and Sandford, 2007, Blind, 2008).
- A sufficient number of experts in a given area needs to be identified to produce a reliable forecast. Further, Delphi surveys run at least two rounds so it is necessary to have samples which are large enough to generate a satisfactory number of responses (Blind, 2008).
- Lack of clear criteria for distinguishing an expert and the lack of sufficient evidence that the judgement of experts is always superior to that of a non-expert (Sackman, 1974, Gupta and Clarke, 1996, Landeta, 2006).
- The sudden science or technology breakthroughs may not be foreseen by the majority of main stream oriented experts (Blind, 2008).
- ‘Lobbying’ - the experts may give ‘strategic’ answers, for instance industry representative may try to avoid or influence future regulations (Gupta and Clarke, 1996, Landeta, 2006, Blind, 2008).
- The Delphi method discourages more radical views. When an individual disagrees with the general opinion of the panel this can result in reduced response stability or in higher level of dropping out (Bardecki, 1984). This, in turn, may promote a convergence process, ignoring important but unorthodox opinions and generating artificial consensus (Sackman, 1974, Stewart, 1987).
- When a Delphi study is conducted using a survey questionnaire, it generally does not shed light on underlying reasoning behind expert opinion.
- Long-term forecasting questions are inherently difficult to answer, which may result in limited accuracy of Delphi results. This, however, applies to all long-term forecasting techniques.

As noted above, one of the problems associated with the Delphi technique is the selection of panel members and particularly who should be considered an expert. Typically, experts will be professionally or scientifically qualified and / or have achieved high status in particular field (Mullen, 2003). However, Linstone (1978) suggests that any individual with relevant knowledge and experience of a given topic

can be considered an expert. Also the number and background of experts involved are important. Linstone (1978) advises a minimum panel size of seven and suggests that accuracy of results deteriorates rapidly with smaller panel sizes and improves gradually with larger numbers. Delbecq et al. (1975), suggest that 10 to 15 participants could be sufficient if their background is homogenous. If the study is based on participants from different backgrounds, more experts are needed to ensure adequate representation of each group. At the other extreme, the Japanese national Delphi study was based on a sample of over 4200 respondents (National Institute of Science and Technology Policy (NISTEP), 2001). Most practitioners agree that a panel of 100 or more qualifies as a large scale Delphi study (Huckfeldt and Judd, 1974). Nevertheless, the size and heterogeneity of the panel will vary depending on the purpose and characteristics of an individual research project.

Further, panellists are seldom selected at random (Hasson et al., 2000) and instead their expertise should be used as selection criteria, especially in forecasting (Mullen, 2003). Purposive sampling or criterion sampling in particular are common in Delphi studies (Hasson et al., 2000). Purposive sampling involves selecting participants that will most benefit the study. Criterion sampling, a type of purposive sampling, involves inviting participants meeting a predefined criterion of importance (Patton, 2002). In Delphi studies, expertise defined relative to the purpose of the study will be the main selection criteria. The selection process may be undertaken by the researcher or by respondents themselves (self-selection). In the second case, the potential participants are asked to judge their personal suitability to contribute to the research upon commencement of the project. This approach carries the risk that the subjective judgements of personal expertise are inaccurate, but may be necessary where expertise criteria are difficult to be objectively measured by an external person. The self-selected members of the panel are likely also to be more enthusiastic about taking part in the study and show a tendency to give over-optimistic responses (Tichy, 2004).

Delphi method in logistics and supply chain management

The Delphi method has been relatively widely applied in the field of logistics and supply chain management. It is particularly widely applied in forecasting of future logistics trends, at different geographical, industrial and operational levels. To date it has been used to forecast changes in the physical distribution of food products in the UK (Walters, 1975, Walters, 1976), project future directions in distribution systems,

logistics and supply chain management at a national and European level (Cranfield School of Management, 1984, Cooper, 1994, McKinnon and Forster, 2000, Runhaar, 2002, Ogden et al., 2005), as well as to investigate factors affecting location decisions in international operations (MacCarthy and Atthirawong, 2003). In the most recent studies the Delphi method was used to investigate factors crucial for supply chain flexibility (Lummus et al., 2005) and to project the future of supply chain management up to 2011 (Melnik et al., 2009). The summary of logistics- and transport-related studies utilising the Delphi technique is shown in Table 4.5.

Justification of the Delphi method in this thesis

The Delphi method has been selected as the most appropriate means of achieving the purpose of the study for a number of reasons. Firstly, due to the recent breaks in the statistical data series, extrapolatory forecasting methods could have not been applied without a great deal of uncertainty about the accuracy of results. Qualitative forecasting was considered as a more reliable alternative. The opinions expressed by specialists directly involved in distribution and supply chain activities and, hence, contributing to the future direction of the key logistics variables, were regarded as the best available indicators of prospective developments in road freight transport operation. In order to maximise accuracy of the forecast and to get a broad spectrum of perspectives a large panel of experts was employed. The survey was used to collect quantitative estimates of the strength and directions of the trends in the series of key logistics ratios. It also permitted statistical analysis of panellists' projections. It needs to be noted here that the aim was not to achieve statistical generalisability of collected data as an 'average' opinion amongst UK's businesses. The aim of the study was not to investigate the industry view of the research problem but to build a best available forecast based on expert evidence. Therefore, in this study the Delphi method has both quantitative and qualitative dimensions as it is based on a structured survey of expert groups and makes use of the knowledge and subjective judgement of participants (Blind, 2008).

Another advantage of combining the Delphi technique and a survey method is that a large dataset enables not only to estimate the average projected value for each variable but, based on differences in opinion, a number of scenarios can be built to reflect alternative future changes in the key ratios.

Author	Topic	Number of rounds	Size of the panel	Study design	Nature of the study
McDermott and Stock (1980)	Forecast of short-term, intermediate and long-term trends and events affecting logistics management	2	40	1 st round: a questionnaire, evaluation of potential future trends along criteria of their feasibility, desirability and probable timing 2 nd round: experts were invited to reconsider their responses in the light of the group opinion	Mostly quantitative
Robeson (1988)	Future of business logistics up to 1995	3	76	1 st round: a questionnaire, identification of 40 potential future trends 2 nd round: a questionnaire, ranking of their potential impact and importance 3 rd round: a questionnaire, review of 20 final trends and comments, final ranking	Mixed (qualitative and quantitative)
Sviden (1988)	Future information systems for road transport	2	54 (first round) 31 (second round)	1 st round: a questionnaire, identification of potential developments in road information technology 2 nd round: a questionnaire, quantification of estimates on significant events, expected performance and cost of future IT systems	Mixed (qualitative and quantitative)
Cooper (1993), Cooper (1994)	Future of logistics in Europe up to 2001	2	“nearly 200”	1 st round: a questionnaire, quantification of relative strength and direction of future trends in European logistics 2 nd round: experts were invited to reconsider their responses in the light of the collective opinion	Quantitative
Monticelli and Carrara (1999)	Freight distribution forecast for the year 2006	2	102	1 st round: a questionnaire, assessment of the impact of the forecasts of specific logistics phenomena on five urban freight transport variables 2 nd round: experts were invited to express their agreement / disagreement with a series of statements derived from the first round responses	Quantitative
McKinnon and Forster (2000)	European logistical and supply chain trends up to 2005	2	129 (first round) 77 (second round)	1 st round: a questionnaire, quantification of relative strength and direction of future trends in key logistics and supply chain variables 2 nd round: experts were invited to reconsider their responses in the light of group consensus	Quantitative
Runhaar (2002), Runhaar et al. (2002)	Developments in cost of freight transport and ability of the logistics sector to absorb it up to 2010	2	87 (first round) 61 (second round)	1 st round: a questionnaire, estimation of developments in rates, transit times and delivery reliability 2 nd round: experts were invited to reconsider their responses in the light of group opinion	Quantitative

Author	Topic	Number of rounds	Size of the panel	Study design	Nature of the study
Tapio (2002b)	Development of scenarios for a transport CO ₂ policy for Finland up to 2025	2	14	1 st round: a questionnaire including a graph showing the development of GDP, road traffic volume and related CO ₂ emissions in Finland from 1970 to 1996. The experts were asked to draw graphs showing the most probable and most preferable future trends up to 2025 and give their views on the reasons for these developments. 2 nd round: the panellist were interviewed after receiving a feedback report from the first round	Mixed (qualitative and quantitative)
MacCarthy and Atthirawong (2003)	Factors influencing location decisions in international operations	Pilot study + 2 rounds	8 (pilot) 20 (first round) 17 (second round)	1 st round: a questionnaire with open-ended questions in part A and closed ones in part B (measuring the relative importance of different factors on a seven-point Likert scale) 2 nd round: an interim report sent back to the participants for feedback and comments. Each participant was asked to record their agreement or disagreement, add comments or suggest revisions.	Mostly quantitative
Ilbery et al. (2004)	Forecasting food supply chain developments in lagging rural regions in the UK	3	17 (first round) 16 (second round) 14 (third round)	1 st round: a questionnaire with an open-ended and closed questions 2 nd round: summary of results from round 1 and a shortened questionnaire 3 rd round: summary of results from previous rounds and a questionnaire containing the same statements as the round 2 questionnaire	Mostly quantitative
Makukha and Gray (2004)	Incentives for entering into strategic partnerships between shippers and logistics service providers and the determinants of their success	2	21	1 st round: a questionnaire with 22 statements, experts were asked to express their agreement or disagreement with the statement and give their comments 2 nd round: a questionnaire consisting of statements where there was a failure to achieve consensus in the first round and new statements derived from the round 1 comments	Mostly qualitative

Author	Topic	Number of rounds	Size of the panel	Study design	Nature of the study
Lo et al. (2005)	Development of a theoretical framework for integrating customer expectations into the development of supply chain management strategies	3	5 (first round) 8 (second round, new panel) 35 (third round, new panel)	1 st round: unstructured interviews, experts were asked to comment on an initial theoretical framework developed based on the literature review 2 nd round: structured interviews, further comments on the framework and assessment of the measures it adopted 3 rd round: a check-point list, experts were asked to indicate how important are the individual measures identified in round 2 in relation to their contribution to the framework	Qualitative
Lummus et al. (2005)	Supply chain flexibility	3	13 (first round) 11 (second round) 10 (third round)	1 st round: a web-based survey, an open-ended question on characteristics that an organisation should have to improve its supply chain flexibility 2 nd round: a web-based survey, rating of the importance of each of 59 characteristics identified in round 1 to supply chain flexibility 3 rd round: the experts were asked to reconsider their responses from round 2 in the light of the group opinion	Mixed (qualitative and quantitative)
Ogden et al. (2005)	Future supply chain strategies over the next 5 – 10 years	3	619 (first round) 308 (second round) 80 (third round)	1 st round: a web-based questionnaire where experts were asked to generate one or two possible strategies or scenarios for 19 supply chain strategy content areas identified for the purpose of the study 2 nd round: a web-based questionnaire where each expert was asked to make a judgement on the likelihood of occurrence of each of the strategies determined in round 1 and to rate their confidence in their likelihood assessment 3 rd round: a web-based questionnaire with the mean and median likelihood and confidence scores of the 2 nd round responses. The experts were asked to reconsider their previous responses in the light of this feedback.	Mixed (qualitative and quantitative)
Melnyk et al. (2009)	Future of supply chain management (2011)	2	24 (first round) 21 (second round)	1 st round: a questionnaire, evaluation of the importance of a number of supply chain issues on a five-point Likert scale 2 nd round: experts were invited to reconsider their responses in the light of group opinion	Quantitative

Author	Topic	Number of rounds	Size of the panel	Study design	Nature of the study
Seuring and Muller (2008)	Core issues in sustainable supply chain management	3	46 (first round) 43 (second round) 42 (third round)	1 st round: an open-ended question on what the most important topics, issues and problems in sustainable supply chain management are 2 nd and 3 rd round: experts were invited to evaluate items identified in the 1 st round on the five point Likert scale	Mixed (qualitative and quantitative)
Deutsche Post DHL (2009)	Customer needs in 2020 and beyond	2	Questionnaire presented to 900 experts but the response rate not given	1 st round: experts presented with 81 theses on the future and asked to assess the likelihood of the occurrence of a particular development and the time it would occur 2 nd round: experts asked to reconsider their evaluations of 20 theses that had been particularly controversial in the first round	Quantitative
PricewaterhouseCoopers (2009)	Transport and logistics in 2030	2 + possibility of further revisions → max nr of rounds 7	48	1 st and 2 nd round: experts were asked to rate 18 theses in terms of their probability of occurrence (0-100%), impact on transport and logistics (5-point Likert scale) and desirability (5-point Likert scale) and provide reasons for all answers (optional)	Quantitative

Table. 4.5. Applications of the Delphi method in logistics and supply chain management research - a summary

Scenario building

As mentioned above, the results of the survey can also be used to construct a number of scenarios. A scenario can be defined as “a hypothetical sequence of logical and plausible (but not necessarily probable) events, constructed in order to focus attention on causal processes and decision points” (Shiftan et al., 2003, p. 326). Scenarios are particularly important in medium- and long-term projections and serve as means of reducing uncertainty associated with forecasting of complex situations dependent on many difficult to control factors (Dreborg, 1996). Scenarios help to assess the possible trajectories for the range of variables being considered and determine the likely consequences for the entire system in question (Chatterjee and Gordon, 2006). However, while developing these trajectories, it needs to be ensured that “there is internal consistency within scenarios envisioned, that assumptions used are not in conflict with each other and that assumptions are realistic and plausible” (Steenhof et al., 2006, p.370). If these conditions are met, scenarios are a valuable tool to study the future development of complex systems (such as e.g. sustainable transport systems) because they can focus attention on the most important drivers influencing issues relevant to policy and decision making (Shiftan et al., 2003).

Scenario building technique has already been widely used to construct projections of future transport activity and / or environmental impacts (Schmalensee et al., 1998, Wright and Fulton, 2005, Chatterjee and Gordon, 2006, Steenhof et al., 2006, Hickman and Banister, 2007, Stanley et al., 2010). According to Steenhof et al. (2006), scenario analyses in the freight sector typically focus on the implementation of policies or technologies and assess their future impacts. They use scenario analysis to project CO₂ emissions from Canadian freight transport by 2012. Three scenarios are considered: a business-as-usual case, a case where road remains a dominant freight transport sector but significant efficiency gains of diesel-powered engines are achieved and the third option assuming a major switch to rail (48% share of all freight transport in 2012) along with improved train technology. The BAU scenario results in the greatest rise in emissions (by 23% or 33% from 2003 and 1990 levels, respectively), while the rail-dominance option emissions fall 10% lower than under the BAU case. The second scenario lies in the middle but still equates to significant reductions when compared to the BAU situation.

Chatterjee and Gordon (2006) explore five alternative scenarios for transport in Great Britain in 2030. The reference case represents business-as-usual trajectory and four other scenarios are adapted from the environmental futures scenarios described in the 1999 UK Department of Trade and Industry's report "Environmental Futures". These four scenarios are named World Markets, Global Sustainability, Provincial Enterprise and Local Stewardship. The reference case scenario forecasts CO₂ road transport emissions (passenger and freight) to grow by 19%. The results of four other scenarios lie between 21% reduction and 9% increase in 2030. Unfortunately, the results for freight vehicles are not presented separately. The same four scenarios are also referred to by Tight et al. (2005). Similarly, Yang et al (2009) construct a number of scenarios to assess the future GHG emissions from transport in California. They start with a reference (i.e. BAU) scenario and then develop a number of options to examine the potential for individual mitigation solutions. Finally they apply a specific case of scenario development, so called backcasting approach, to identify strategies that can achieve the GHG emissions reduction target set for California (80% by 2050).

Backcasting is a particular approach to scenario building (Hickman and Banister, 2007). However, while "scenarios are developed step by step by logical reasoning from the present situation into the future" and "usually are chosen just to give a feel for the scope of possibilities, whether these are desirable or not" (Dreborg, 1996, p.816), backcasting is a kind of scenario study presenting alternative ways to achieve the desired future outcome. As explained by Hojer and Mattsson (2000), "backcasting aims to understand what a future situation, in which the targets are met, could look like and how it could be attained" (p.629). Thus, backcasting is concerned not with predicting what futures are likely to happen but with setting a long-term target and identifying paths along which this desired future outcome can be achieved (Dreborg, 1996, Akerman and Hojer, 2005). Akerman and Hojer (2005) also stress that "a full backcasting study is only suitable when the targets do not seem to be reached by adjustments to a business-as-usual development" (p.1945). Further, "if used in a clever way, backcasting can be helpful in opening eyes to overlooked options" (Hojer and Mattsson, 2000, p.629) and can generate 'creative and radical solutions' to current challenges (Hickman and Banister, 2007).

According to Dreborg (1996), the following characteristics favour backcasting:

- The research problem is complex and dependent on a number of variables.

- There is a need for a major change, i.e. marginal changes within the prevailing order will not be sufficient.
- The dominant trends are part of the problem.
- The problem to a great extent is a matter of externalities, which the market cannot treat satisfactory.
- The time horizon is long enough to allow a considerable scope for deliberate choice.

The problem of future environmental impacts of transport fits very well into these characteristics and backcasting becomes increasingly popular method in sustainable transport studies. Banister and Hickman (2006) and Hickman and Banister (2007) apply a backcasting study approach in order to examine the possibilities of reducing UK transport (passenger and freight) CO₂ emissions by 60% by 2030 below the 1990 levels. They assess various policy measures and investigate how they can be effectively combined to achieve the desired reduction target. Analogous study was also conducted for Scotland (Hickman et al., 2007).

In a similar vein, Stanley et al. (2010) investigate the implications of possible CO₂ reduction targets for road transport sector in Australia (20% reduction by 2020 and 80% reduction by 2050, relative to 2000 levels). They apply a backcasting approach and consider six key reduction measures to achieve the suggested targets. However only one measure regards HGVs directly, namely reduction of forecast fuel use for road transport. The authors develop a number of scenarios to illustrate what changes would be required to achieve the proposed targets. Akerman and Hojer (2006) apply backcasting approach to investigate measures required to ensure that future transport system in Sweden is sustainable enough to be consistent with the target of stabilisation of the CO₂ concentration in the atmosphere at 450 ppm by 2050.

Scenarios will be constructed based on the Delphi results. Similar approach was adopted by Shiftan et al. (2003). They used Delphi survey results to develop scenarios in order to explore the future development of transport system in Tel-Aviv. In this thesis, the BAU case will be based on the mean values of experts' responses. A number of scenarios will be developed based on identified differences in opinion and will also incorporate some predictions currently available in the literature. If the results of the scenario analysis do not demonstrate sufficient reductions in the future CO₂ emission

levels, a backcasting approach will be applied to demonstrate which changes to the key logistics variables would be required to achieve significant improvements in environmental performance of the industry, e.g. in line with the national GHG emission reduction targets.

4.5.3. Spreadsheet modelling

Spreadsheets have become a major tool supporting decision making processes, managerial planning and analysis (Coles and Rowley, 1996, Seila, 2006). Spreadsheet software has been extensively and effectively used in the analysis of logistics and supply chain-related issues (Tyworth and Grenoble, 1991, Smith, 2003). It can be used on all levels of logistical decision making, supporting both strategic as well as operational planning (Smith, 2003). One of the important features of using a spreadsheet model is the ease of what-if, or scenario, analysis. A user can change one or more variables in the model to see how this will affect the output. This allows the user to contemplate the implications of various scenarios (Seila, 2006). Using a spreadsheet model also permits an analysis of the value a particular variable must take if the desired output is to be achieved (Coles and Rowley, 1996).

Spreadsheet models have the advantage of being easy to develop, understand and use, while being equipped with sophisticated functions to perform more complicated computations (Seila, 2006). They are also equipped with good graphic features for displaying the results (Tyworth and Grenoble, 1991, Smith, 2003). The spreadsheet packages are available for all of the major desktop operating systems, with Microsoft Excel being the most prevalent (Seila, 2006). Most spreadsheets are programmed in a way that ensures their connectivity to other applications (for instance they allow to import or export data from / to other programmes).

According to Coles and Rowley (1996), modelling using spreadsheet should embrace the following stages:

- Conceptualisation of a problem;
- Model design;
- Model construction;
- Validation and verification;
- Documentation;
- Implementation and use.

A spreadsheet model has been constructed following the above steps and calibrated using 2006 freight-related data from official data sources and linking HGV activity to a series of transport-related externalities. The model was first used to assess the external impacts of road freight transport in 2006 (Piecyk and McKinnon, 2007). It was then redesigned for the purpose of this thesis and updated with 2007 data. By calibrating the model with the output from the Delphi survey, it has been used to forecast the CO₂ emissions from road freight transport in 2020.

4.6. Reliability and Validity of Research

Reliability and validity are crucial for a research project to be recognised and approved by the scientific community. Mentzer and Kahn (1995) emphasise that there is a need for more attention to be paid to reliability and validity in logistics research as much of it “remains largely managerial in nature and lacks a rigorous orientation towards theory development, testing and application” (p.231). Similarly, Craighead et al. (2007), argues that “as the research universe of the logistics discipline continues to expand beyond traditional operational aspects of logistics, methodological rigour will also increase in importance” (p.23).

Reliability is concerned with the credibility of the research findings. The findings are considered reliable if they can be repeated. Reliability is very important in positivistic studies and tends to be tested by replicating a research study and comparing the results. Under an interpretive paradigm, reliability is concerned with whether similar observations and interpretations can be made on different occasions and by different observers (Hussey and Hussey, 1997).

Validity refers to how accurately the research findings represent the investigated phenomena (Maylor and Blackmon, 2005). Mentzer and Kahn (1995) and Mentzer and Flint (1997) differentiate between four components of validity:

- **Validity of the statistical conclusion-** refers to whether there is a statistical relationship between the two phenomena, i.e. whether the independent variable covaries with the dependent variable.
- **Internal validity-** where there is a relationship between the two phenomena and it can be assessed to be causal, i.e. whether the independent variables cause the dependent variable.

- **Construct validity**- concerns whether the measures assess what they purport to assess.
- **External validity**- is defined as the degree to which the research findings can be generalised to the broader population.

Further, Mentzer and Flint (1997) conclude that “the only way to thoroughly research any concept in logistics is through the research concept of triangulation” (p.213). The data and methodological forms of triangulation were applied in this study. Mentzer and Kahn (1995) note that mail surveys are useful for ensuring the external validity of research. However, they lack a high degree of control, thereby diminishing internal validity. The Delphi survey conducted in this study was internet-based. Online surveys are, by their nature, very similar to mail surveys, the main difference being the use of a more modern means of communication. To mitigate a potential lack of internal validity the focus group method was used. It contributed also to ensuring better construct validity by confirming that practitioners understand key concepts in the same way as they are defined in the scientific literature and that the proposed measures are considered appropriate. On the data collection and analysis level, efforts to ensure sufficiently large sample size and measures such as the testing for non-response bias were applied to maximise the reliability and validity of the research.

Halldorsson and Aastrup (2003) challenge the traditional way of judging logistics research that is based on concepts of validity and reliability. They draw attention to parallel criteria from interpretivist research approaches, based mostly on a concept of trustworthiness. Trustworthiness combines the qualities of credibility, transferability, dependability and confirmability. The authors stress that their aim is not to replace traditional criteria but to introduce these alternative views on research quality and reflect on their possible role in logistics. As this thesis is grounded in the critical realism philosophy, following the recommendations of Riege (2003), validity and reliability were the main criteria used to evaluate the research design.

4.7. Conclusions

This Chapter provided a comprehensive review of the main philosophical perspectives in scientific research and resulting methodological choices. The purpose was not to prove that a particular research paradigm or associated methodology is better than the others. As different types of research problems require different solutions in terms of

research approach and choice of method, the aim was to provide a justification for the research process adopted in this particular project.

Based on the critical realist paradigm, this research acknowledges that supply chain, logistics and freight transport systems have very complex structures and are subject to a number of different, sometimes contradicting, pressures. Some of the pressures can be correlated with trends in other socio-economic variables (e.g. GDP, spatial dispersion of population, levels of industrial activity, etc.). Thus, changes in road freight transport activity can be partly explained by the changes in these underlying variables. However, these systems are also social structures and depend on the decisions of agents operating them. As such, they are also shaped by a number of human decisions and are subject to a range of internal and external pressures, as shown in Chapter 3. The triangulated approach was applied in the design of this research to fully comprehend and analyse this complexity.

This chapter also presented and justified the process of selecting research methods: focus groups, Delphi survey and spreadsheet modelling. All these methods have been successfully applied in supply chain, logistics or transport research before. The selection process involved assessment of the strengths and weaknesses of each method in order to ensure that there is a synergy in advantages and elimination of potential problems associated with each approach in the research process. Finally, the validity and reliability of the research were also considered.

Chapter 5. Factors Influencing the Future of Logistics - Focus Group Discussions

Aims of the chapter:

- *To outline the focus group research process*
- *To discuss findings of the focus group research and their likely implications for the future of the freight transport sector*
- *To demonstrate the contribution of focus group discussions to the later stages of the research process*

This chapter is the first of three presenting empirical findings of the research. As discussed in the previous section, the focus group method was chosen for the first stage of the research project. The aim of the focus group workshops was to canvass expert opinion on the main factors influencing key logistics parameters which, in turn, determine the environmental impact of freight transport. The analytical framework introduced in Chapter 3, has been used to map the complex inter-relationships between economic growth, a series of key logistics variables and a range of freight-related externalities. Supply chain structure, modal split, vehicle utilisation and fuel management have been identified as top-level logistical and supply chain variables. They have been then broken down into more detailed key ratios e.g. average length of haul or number of links in the supply chain. The focus group discussions aimed to identify the potential determinants of the changes in each of the key ratios.

The combined confirmatory - exploratory approach was adapted to seek in-depth understanding of the complex reality of logistics and supply chain management and to test the accuracy of factors identified in the literature review. The fast - changing market environment results in the current concepts and business models becoming rapidly obsolete and replaced by new ones. Hence, it was necessary to ensure that the findings from the literature review are still applicable to the current logistics practices and to investigate any new factors that might have gained importance recently.

5.1. Research Design and Analysis

The focus group discussions were held between late March and early June 2007. A team of six researchers from Heriot-Watt and Cardiff Universities supported by an administration officer was involved in planning, organising and facilitating the meetings. The author belonged to this team of researchers.

5.1.1. Sample

A series of seven focus group discussions were conducted in five different locations across the UK: two sessions in London, two in Nottingham, one each in Birmingham, Edinburgh and Cardiff. Initial invitations were sent out to 156 potential participants 26 of whom replied positively. After follow-up calls and 21 further invitations, more participants agreed to attend increasing the total number to 75, giving an acceptance rate of 42 %. The final number of attendees was 58 which gives a response rate of 35% and a rate of absence of 23%. The number of participants per group varied between 5 and 13.

In order to identify potential differences in opinion between participants representing different types of supply chain members, the results were analysed using a classification based on that developed by the European Logistics Users, Providers and Enablers Group (ELUPEG). However, in order to include a large array of perspectives, this categorisation was broadened to incorporate the following types of organisations:

- **Manufacturers** – organisations which ship their products to a wide range of external customers. Typically, production would be the primary focus of their operations.
- **Retailers** – businesses which receive products from a number of producers. They may also have an internal distribution network and / or resale products to ultimate consumers.
- **Providers** – organisations providing transport and other logistics services.
- **Enablers** – businesses providing technology, solutions or consultancy services to facilitate logistics operations.
- **Trade Bodies** – organisations representing a number of businesses from a particular sector.

- **Policy Makers / Lobbyists** – governmental and non-governmental bodies which may influence the external environment within which logistics processes take place.

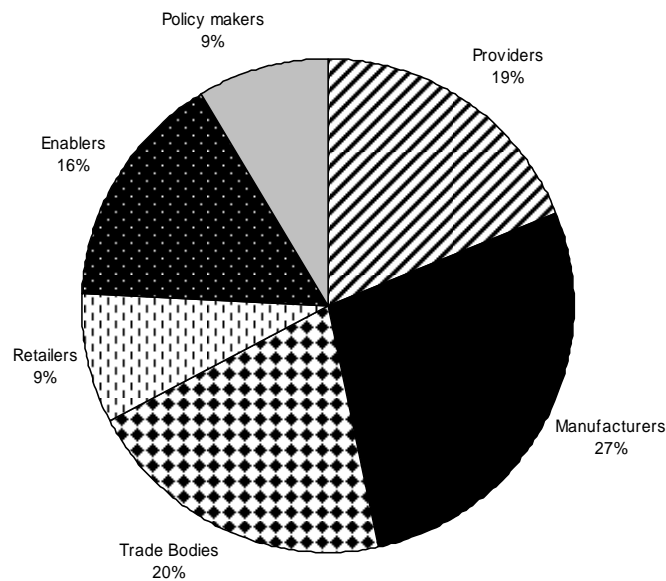


Figure 5.1. Sample composition by type of organisation (n = 58)

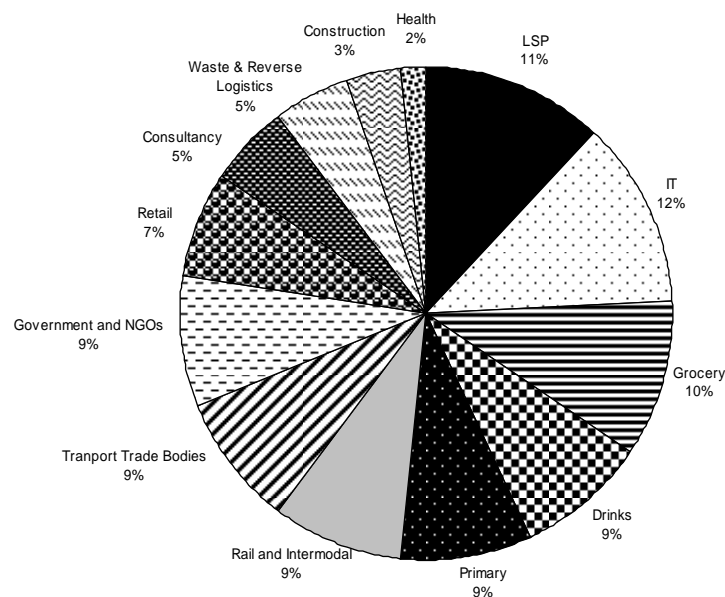


Figure 5.2. Sample composition by industry type (n = 58)

Further, the results were also analysed from an industry sector perspective. Sectors represented include: logistics service provision (LSP), information technology (IT), grocery, drinks, primary, rail and intermodal transport, transport trade bodies, retail, consultancy, waste & reverse logistics, health and construction. Figures 5.1 and 5.2

depict the composition of the sample by type of supply chain member and industry sector.

5.1.2. Research process

A pilot focus group was organised to trial the planned organisation of the sessions and comprehensibility of the questions, which proved to be effectively structured for the research purposes (Morgan et al., 1998). In order to assess the adequacy of the sampling method in terms of the group composition the degree of convergence or divergence of the participants' comments was considered afterwards to ensure that the sampling approach optimised the level of discussion (Morgan, 1988, 1993, Krueger, 1994). As the pilot focus group proved to be successful, the results of the discussions were included in the overall research findings.

A short presentation was prepared outlining the recent changes in four sets of key parameters relating to supply chain structure, freight modal split, vehicle utilization and fuel management and the factors that had contributed to these changes in the past. This presentation was shown to the experts at each session. The following structure of a meeting was adopted. Recent trends in each parameter were outlined and factors which are believed to have influenced them were listed. After this participants were asked to comment on the factors and to raise other issues they found relevant. This procedure was followed for each of the variables. However, after two sessions it was felt that this approach might have prompted the range of responses by prematurely drawing the attention of interviewees to past causes. Therefore, the structure of the workshops was modified slightly. The participants were first shown a graph illustrating the past changes in a given parameter. Then they were encouraged to discuss what the future direction of the trend would be, what factors were influencing this parameter and if they were likely to change in the future. The moderator tried to stimulate discussion by asking additional questions in order to explore all dimensions of the issue investigated. After that the delegates were shown lists of factors that were likely to have had an influence on the past changes in the parameter under discussion. At this stage they had a chance to consider their responses and to add any extra comments. All researchers were involved in moderating the discussions interchangeably, including the author. This helped to eliminate a potential risk of a single facilitator biasing the results because of their particular facilitation style.

In the feedback forms distributed after each focus group meeting the participants were asked to evaluate the content, usefulness and the level of interest in of each session. The delegates seemed to enjoy the experience and generally assessed the discussions as constructive and informative while at the same time providing a wider perspective on sustainability issues. The opportunity to network and exchange opinions and examples of good practice were amongst the most often mentioned gains from taking part in the exercise.

After the final analysis was completed, each participant was sent a report of the main findings. This was made available exclusively to the focus group contributors. In a covering email circulated with the report further feedback was invited. Only one delegate responded to this invitation. Additionally, a feedback session for all participants was organised. A presentation summarising the results was prepared and shown to the participants. In this way they had a chance to discuss the overall findings and point out any potential misinterpretations in the analysis. The general feeling was that the findings accurately represent the participants' views and opinions. The feedback session played an important role of confirming the credibility and accuracy of the results.

5.1.3. Data analysis

As focus group discussions belong to the category of qualitative research, the data collected can often be difficult to analyse (Kreuger, 1994). During each session detailed notes were taken by the research team. Additionally, digital recorders were used. The participants had been forewarned that the discussions were going to be recorded and assured that views expressed during the meeting would remain anonymous and confidential. It was also possible for the note-takers to identify delegates for analytical purposes given the limited group sizes. The data were then synthesised and factors affecting the supply chain structure, freight modal split, vehicle utilization and fuel management rated according to their frequency of occurrence. This frequency was analysed by focus group, type of participant and industry sector. It is believed that following this procedure has helped to ensure the credibility and accuracy of the results.

All workshops were a rich and informative source of insights into the research subject. Each meeting resulted in the identification of key factors influencing the major logistics trends as well as the likely direction and intensity of these trends in the future. After

three sessions, the general feeling amongst the research team was that the number of new observations being made was diminishing. However, as participants came from different industry sectors and types of organisation, new company-/ sector-specific points were raised each time. Figure 5.3 shows the total number of comments¹⁰ and the number of new points introduced in each meeting. The groups with smaller numbers of participants seemed to be more productive in terms of a number of comments generated, probably because each delegate felt less inhibited and had more time to develop their arguments. This enabled the participants to discuss in greater depth recent trends and underlying causes. The number of new points raised flattened at a quite low level after the third workshop, which confirms the ‘theory saturation’ concept presented for instance by Johnson and Christensen (2004). According to these authors, the research process is complete when theoretical saturation occurs, i.e. when no new concepts are emerging from the discussions and the previous comments are well validated. From the third session onwards, only a limited number of new issues was raised, however, the overall number of comments remained relatively high in the later sessions providing validation of the points raised in the earlier workshops.

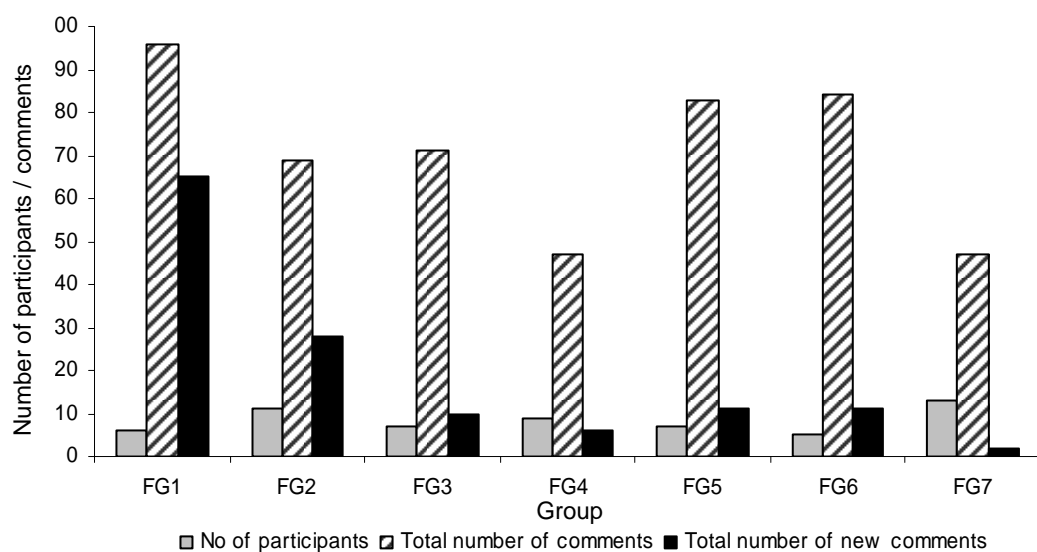


Figure 5.3. Theory saturation in the focus group discussions

Similar analysis was conducted of the total number of comments and new comments per participant attending each of the workshops (Figure 5.4). It confirmed that there was an inverse correlation between the number of participants taking part in the discussion and the number of comments per person. Better attended groups (FG2, FG4 and FG7) resulted in the lowest number of points per person. Conversely, workshops with lower

¹⁰ A comment is defined as a point or issue raised on a particular subject.

attendance levels (5-7 participants) delivered the richest discussions. It needs to be emphasised that the quality of the data obtained from the focus group discussions is not simply a function of the number of people invited, but depends on many different factors like the experience, knowledge or personality of the participants. Although almost all the participants were senior executives with extensive experience, the nature of this experience and their personalities differed. The group dynamics also varied with the particular mix of personalities assembled at a particular event. This distorted the relationship between the size of group, the level of interaction and the number of points raised. Based on this research, the optimum number of invitees appears to lie between five and seven. The number of new comments per participant followed the same pattern.

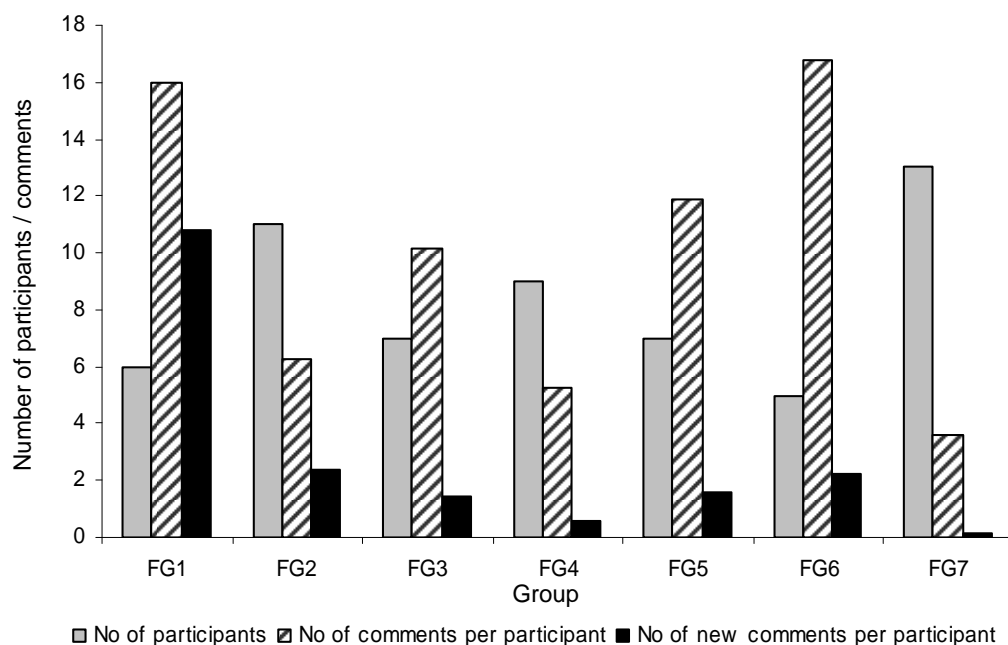


Figure 5.4. Number of comments / new comments per participant

The analysis of the focus group transcripts provided further interesting findings. Some themes stimulated more lively and fruitful discussions than others (Figure 5.5). The issue of modal split, particularly the concept of transporting more freight by the rail, generated the greatest number of comments, even although it was not discussed in one of the workshops (due to lack of time). Similarly, the matter of vehicle utilisation, mainly in terms of maximising the loading factor, was discussed in great detail. On the other hand, the macro-level concepts like handling factor or carbon intensity of fuel proved to be more difficult and generated fewer comments. However, it seems reasonable that the issues attracting greater media coverage (e.g. modal split) or faced by the participants in their everyday business activities (e.g. efficient loading of the

vehicles) would stimulate more interest than more theoretical concepts requiring technical knowledge (e.g. carbon content of different types of fuel).

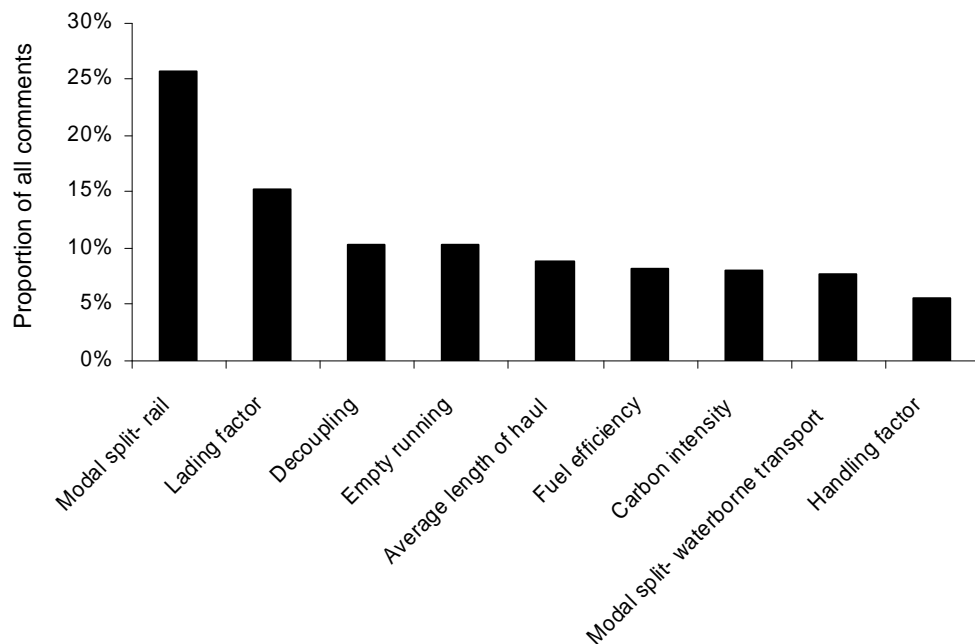


Figure 5.5. Comments received by subject as a percentage of total comments

In terms of the number of comments per participant type the enablers group proved to be the most productive (Figure 5.6). This is most likely because this group had the broadest practical overview of logistics and supply chain management issues. Similarly, customers and carriers groups expressed their opinions more frequently than manufacturers, trade body representatives or policy makers.

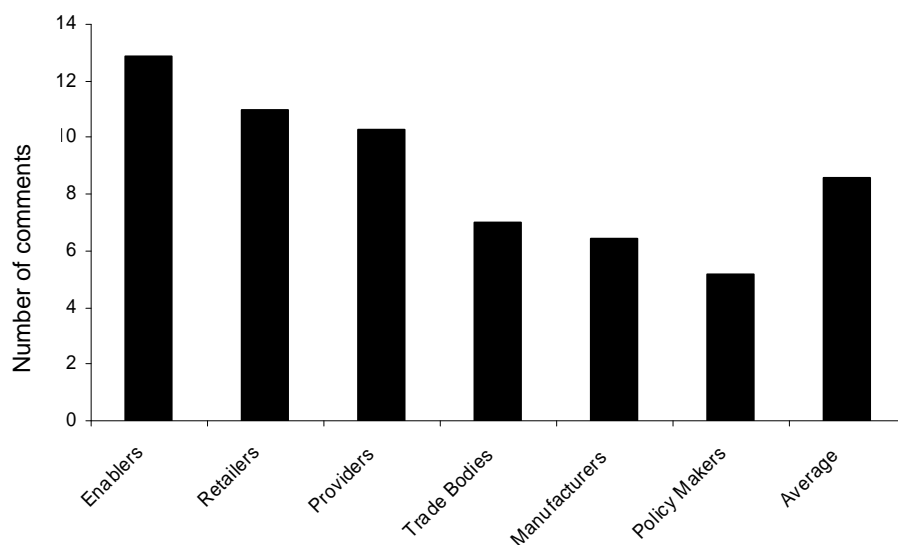


Figure 5.6. Number of comments per participant (by type of organisation represented)

In terms of industry sectors, the representatives of LSPs, primary, retail, IT and health sectors provided the greatest number of comments per person (Figure 5.7). However, It would be unwise to draw any general conclusions about these sectoral variations as the total sample of focus group participants was relatively small. Again, it needs to be emphasised that all results presented here are specific to this research project and should not be generalised to the industry as a whole.

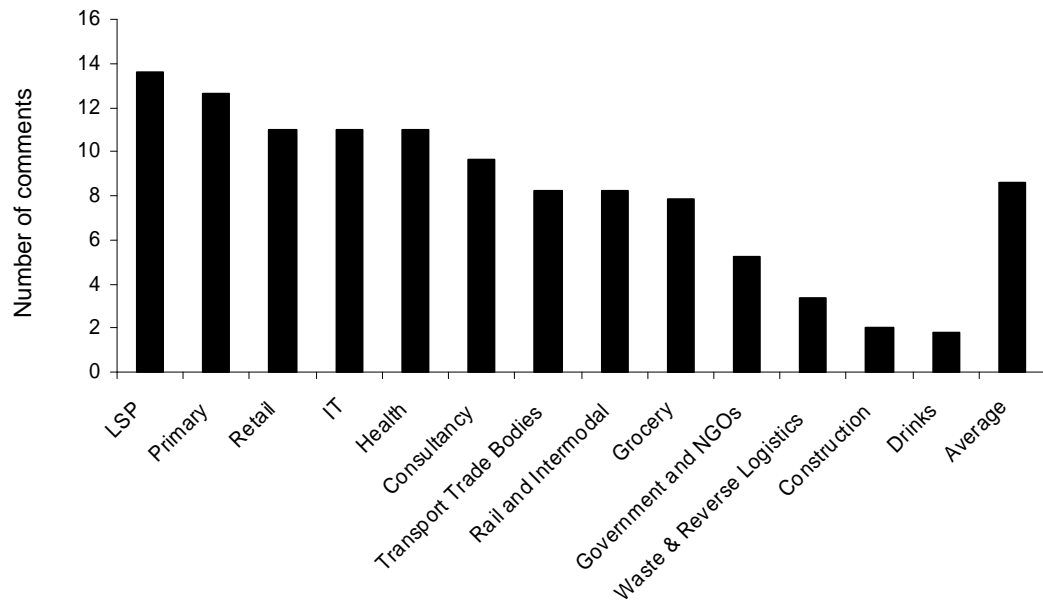


Figure 5.7. Number of comments per participant (by industry represented)

5.1.4. Assessment of the research in the light of focus group theory

Although focus groups are a popular research method within social sciences and management studies, it was shown in Chapter 4 that their use within logistics is still relatively limited. Furthermore, there is a lack of methodological literature specifically on the application of the focus group method in transport, logistics or supply chain management (Sanchez Rodrigues et al., 2010). Hence, general recommendations from social science-related literature on focus group research were followed. This section explains how the processes of planning, execution and analysis in this research project adhered to the focus group theory.

As it was noted above, based on data collected it was concluded that the optimal number of participants per group lay between five and seven, which is consistent with the literature. However, each of the meetings was different in terms of group composition (Table 5.1). Although at the planning stage, possibilities of influencing focus groups

composition were somewhat limited (due to the uncertainty about who was going to accept the invitation and take part in the discussions), efforts were made to maximise the probability of including participants from different types of organisations and industry sectors in the research. The balanced composition of groups allows sufficient scope for comparison and contrast between participants and leads to a more productive, rich and comprehensive discussion on the subjects investigated (Krueger, 1994, Morgan et al., 1998). A well-balanced composition was achieved by sending invitations to each of the meetings to a diverse sample of companies. Additionally, in order to ensure good quality of discussion, the invitations were addressed to senior transport-, logistics- or supply chain-related employees within the organisations invited.

Focus group session	Type of organisation represented						Number of industry sectors represented	Group size
	Manufacturers	Providers	Retailers	Enablers	Trade Bodies	Policy Makers and Influencers		
FG 1	1	2	1	1	1	0	5	6
FG 2	2	2	1	2	2	2	7	11
FG 3	1	2	0	2	2	0	5	7
FG 4	3	2	1	1	1	1	7	9
FG 5	1	2	1	2	1	0	5	7
FG 6	2	0	1	0	1	1	4	5
FG 7	6	1	0	1	4	1	7	13
Total	16	11	5	9	12	5		58

Table 5.1. Group size and composition

FG7 was the most unbalanced in composition, with manufacturers and trade bodies constituting 77% of the participants. FG2 and FG4 were the only two meetings where the representatives of all types of supply chain members were present, while FG2 was also the most representative one in terms of the number of invitees from different business backgrounds. Surprisingly, the performance of both FG2 and FG4 groups was rather average in terms of the total number of comments and the number of new comments both per participant and per group. Further, the performance of FG7 was comparable. The best performing groups (FG1, FG5 and FG6) were reasonably well balanced in terms of the type of organisation and industry sector represented. They were also smaller in size, as discussed above. This suggests that, in this research project, size of the group influenced the quality of data collected to a larger extent than the mix of participants.

The meetings were organised in five locations across the UK. The locations were chosen taking into account major logistics flows and business locations within the country. Consideration was also given to the geographical location of potential participants at the planning stage, to maximise the response rate by minimising the distances they had to travel to the venues. Additionally, venues selected for the meetings were easily accessible by public and private transport. Although every venue had a slightly different layout, in every case a room was arranged in a way that ensured that all participants were able to listen to the facilitator and other participants. Hence, in choosing the locations / venues the recommendations from the research literature (e.g. Krueger, 1994, Morgan et al., 1998) were strictly followed.

As mentioned earlier, all researchers acted as facilitators interchangeably. Although appointing of a professional moderator is sometimes recommended in the literature, it was felt that in this case a good degree of logistics knowledge was needed to lead the discussions effectively. Hence, the decision was made to leave the facilitation 'in-house'. As mentioned before, use of different moderators helped to eliminate any potential bias and added credibility to the research finding, as recommended by Bryman and Bell (2007). Further, all supporting information was presented in a neutral way to avoid any initial prompting of participants towards topic discussed.

As the literature suggests, in logistics-related focus group research, an unstructured approach is more popular for exploratory studies and a structured approach for explanatory studies (Sanchez Rodrigues et al., 2010). The objective of this study was to canvass expert opinion on the main factors and key ratios influencing the environmental impact of road freight transport. The determinants of the past changes in each of the key ratios were identified during the literature review and the first objective of conducting the focus group research was to test the validity of these potential determinants. Further, their relative importance and any new factors that may have been relevant were explored. Thus, the study was confirmatory-exploratory in nature. Similarly, the approach taken by the research team evolved from structured to semi-structured as sessions progressed. The most visible stage in this process was the change in presenting supporting information after the second meeting, as described above. Also, the facilitation style was modified slightly during the course of meetings with moderators increasingly giving more freedom to the participants and intervening only in the cases where discussion was diverging from the subject discussed.

After the series of meetings was completed, the recordings were transcribed. “Data analysis consists of examining, categorising, tabulating, or otherwise recombining the evidence, to address the initial propositions of a study” (Yin, 1994, p. 99). Transcripts and notes taken at the events were used to analyse the data. Transcript-based analysis can be very time-intensive, but it is the most rigorous approach (Krueger, 1994). As discussed in Chapter 4, at the analysis stage, Krueger (1994) recommends considering the following: words, context, internal consistency, frequency and extensiveness of comments as well as their intensity.

All of these were taken into account during the analysis. As the topics discussed were technical in nature, hence unlikely to cause deep emotional reaction, the focus of the analysis was on the literal meaning of issues mentioned. The extent and frequency of comments were given particular attention. In a typical focus group session, some topics may be discussed by more participants (extensiveness) and some comments are made more often (frequency) than others. The topics raised more frequently and / or discussed more extensively are likely to be more important and relevant. However, they may be more familiar, controversial or simply easier to discuss for those involved in research (Krueger, 1994). As the main purpose of the focus group research was to identify the issues for further investigation, the frequency of comments was considered to be a good indicator of the importance of factors discussed. The theory saturation was tested as well in order to confirm the completeness of the findings.

To summarise, the recommendations from the generic focus group literature were applied at all stages of the research considering the circumstances of the logistics discipline. The experiences from the planning, conducting and analysis phases confirmed that most of the methodological recommendations found in the management and social science research literature were beneficial. The focus group method was shown to be a good means to achieve in-depth insight into the research problems under investigation.

5.2. Focus Group Results

After analysing the transcripts from each session the factors influencing supply chain structure, freight modal split, vehicle utilization and fuel management were synthesized and rated according to their frequency of mention. There are different measures of how much emphasis a topic was given. One way of doing this, is to combine the number of

comments the issue has received and the number of discussions during which the topic was mentioned. This can eliminate the potential bias likely to occur when the issue is the subject of a long and detail discussion but only during a limited number of meetings. This ratio was calculated for each of the variables and this confirmed the validity of frequency of comments as a measure of relative importance. All comments raised by the participants are discussed in this Chapter. However, only issues mentioned twice or more are shown on the frequency graphs. The summary of the findings is presented below.

5.2.1. Relationship between economic activity and road freight transport growth

The focus group participants identified 14 different factors that may influence the breakdown of the relationship between economic growth (measured as growth in GDP) and the intensity of road freight transport. The eight most frequently mentioned factors are shown in Figure 5.8. The results suggest that the most important reason for the reduction of transport intensity of British economy is offshoring of manufacturing and high dependence on imported products. *“What would the situation look like if instead of the UK road tonne-kms, we had tonne-kms related to the UK consumption?”* was the first question posed when the decoupling graph was shown at the first meeting and similar comments were frequently repeated at every event. When goods are imported from overseas, all transport between different stages in the production process also happens abroad and it is not recorded in the British transport statistics. This results in a significant reduction in tonne-kms moved in the UK. However, in a broader perspective, offshoring actually increase transport intensity at a global level, as all the product-related movements are still happening but they now take place outside the country. Offshoring of manufacturing was mentioned in almost every meeting, apart from one, and with equal frequency across representatives of different types of organisation. It also generated twice as many comments as the next most frequently discussed issue – changing mix of GDP elements. It was felt strongly that the offshoring trend is going to continue in the future and that an increasing proportion of goods consumed in the UK will be imported from locations like China, India or Eastern Europe.

The second most frequent reason given for the decoupling of GDP growth and road freight traffic growth was the increase of services’ share of the GDP composition. Statements like for example: *“Service-based industry may be the reason for decoupling. Services do not generate a lot of tonne - kilometres”*, were made at each meeting. With

the expected further decline of the manufacturing sector, the British economy was predicted to be even more service-based in the future. Due to their intangible nature, services generate significantly less freight traffic than traditional goods per £1 billion of output, thus contributing to a reduction in the total tonne-kms.

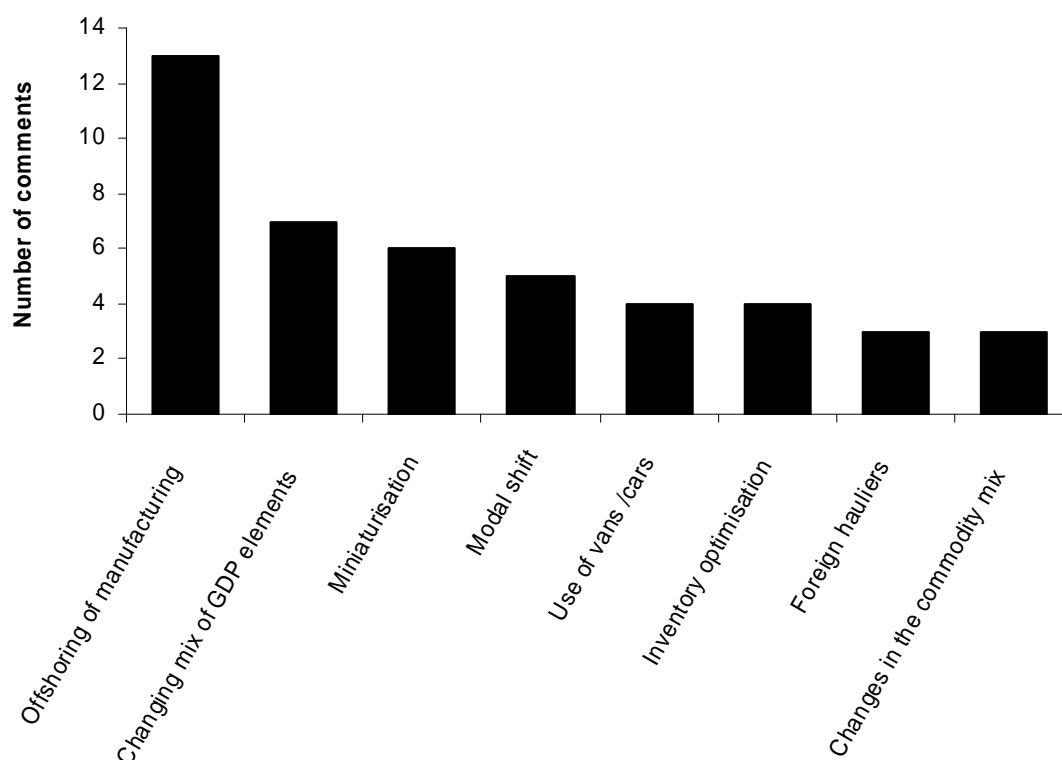


Figure 5.8. Factors contributing to the decoupling of economic growth and road freight transport growth

With technological advancements, products are becoming smaller but, at the same time, they often increase in value. Miniaturisation of products and their higher value affect the decoupling trend in two ways. More valuable goods contribute to a greater increase in GDP, if they are manufactured or assembled in the UK. Also, as goods are becoming smaller and lighter, they generate less tonne-kms for the same number of products moved, assuming the same distance travelled. An example of a flat screen TV unit was frequently given here. As, regarding to the participants, manufacturing processes are very likely to be increasingly overseas-based, the domestic freight traffic reduction effect of miniaturisation is going to be more pronounced than contribution of more valuable manufacture to a faster GDP growth.

A decline in HGVs' share of the freight market was expected due to two factors: changes in modal split resulting in more goods being moved by rail or waterborne

transport and more freight being transported by vans or even passenger cars. The later trend was felt to be particularly pronounced on the last leg in the supply chain, especially in the light of developments in urban distribution and increasing frequency of home deliveries. Both factors are going to contribute to a decline in tonne-kms transported by HGVs. However, this is not going to be an absolute reduction in the total freight traffic but rather displacement of cargo to other transport means. GDP should not be significantly affected by these changes.

Inventory optimisation, mostly through better IT solutions, was also believed to eliminate unnecessary freight traffic. As companies are becoming ever more successful in managing their inventories, logistics planning becomes more coordinated and there is less need for emergency stock movements within supply chains.

Another reason for the decoupling of GDP and road freight traffic growth was felt to be the increased penetration of the domestic (cabotage¹¹) and international (especially in the case of imports) haulage market by foreign carriers. Their activity is not recorded in the CSRG, thus does not lead to an increase in HGV tonne-kms. However, foreign vehicle activity is captured in the NRTS and it is believed to partly explain the difference between these two estimates of HGV activity (McKinnon, 2007a). As UK fuel duties were forecast to remain well above the EU average, further penetration of road freight market by foreign carriers is expected.

Changes in the commodity mix transported by road were given as another cause for the decoupling trend. There has been a significant increase in the share of foodstuffs and miscellaneous products¹² in the total volume transported by HGVs (Figure 5.9), since early 1990s. As loads containing these categories of goods are typically limited by volume (34% of loads containing foodstuffs and 38% of miscellaneous shipments in 2007 (Department for Transport, 2009a)), vehicles ‘cube out’ before they ‘weight out’, hence less tonne-kms are recorded on a single trip. With disappearance of primary processing and manufacturing industries, further increase in the proportion of lighter goods transported by road was expected.

¹¹ Cabotage – transport of goods between two points in the same country by an operator registered in another country.

¹² This category includes machinery and transport equipment, other metal products, textiles, clothing, packing containers, packaging only, pallets, parcels, household waste, unknown commodities, etc.

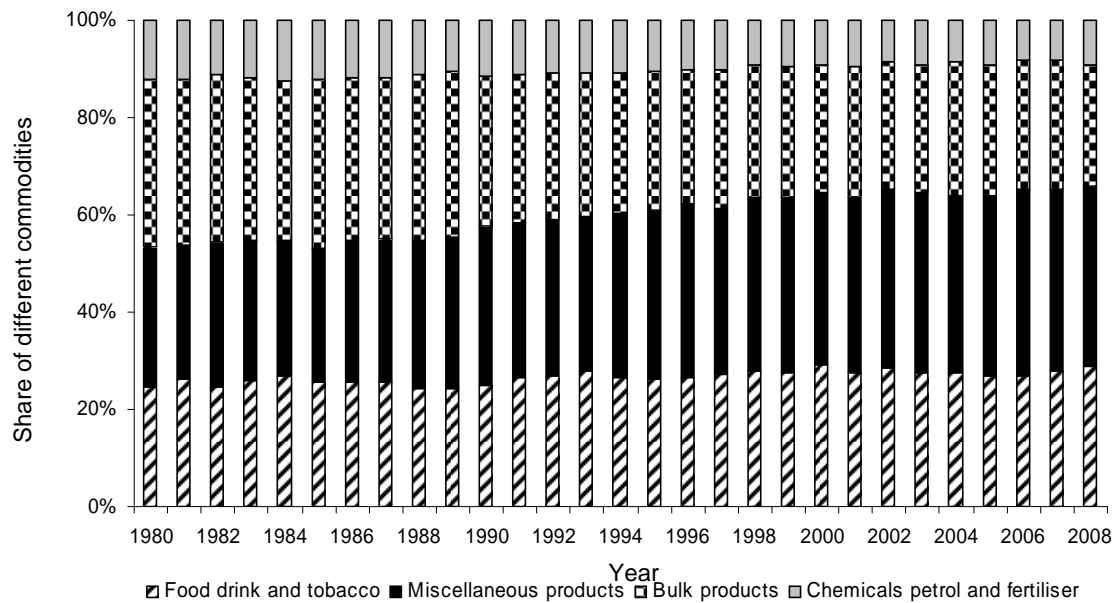


Figure 5.9. Changes in commodity mix moved by HGVs
Source: Department for Transport, 2009a

Wider sourcing, raising fuel prices, less exports, clustering of suppliers around manufacturers, improvements in quality of products were other factors believed to affect the growth in truck tonne-kms. Wider sourcing, process at an advanced stage within the UK is likely to result in more tonne-kms, which could reverse the decoupling trend. If wider sourcing is considered on a global scale, it may reduce the volumes of domestic freight traffic but generate more tonne-kms internationally. The rest of the points raised was expected to reduce road tonne-kms.

A possible change in the methodology of freight and GDP data collection was frequently listed as one of the reasons for the decoupling. However, according to government officials no changes have been made to the methods they use to survey economic or transport variables over that period, which could have affected the consistency of the time series data.

5.2.2. Supply Chain Structure

In terms of the possible changes in the supply chain structure two factors were discussed: handling factor and average length of haul. As defined in Chapter 3, handling factor represents the average number of links in the supply chain while average length of haul corresponds to the average length of these links. According to the experts' opinions, the relative strength of centralisation and decentralisation forces will have the greatest impact on the supply chain structure. It was generally felt that even though the

cost pressures favouring centralisation are still strong, this trend has reached its maximum extent and we may see some reversal of this trend in the future. Also, there is a strong link between handling factor and average length of haul, i.e. factors reducing the number of links in the supply chain are very likely to increase the distance between them and vice versa.

Handling factor

Handling factor will be subject to two conflicting pressures. Developments in primary distribution with more frequent consolidation initiatives and a growing number of companies operating hub-and-spoke type of networks are likely to increase the number of links in the chain and inflate the handling factor (Figure 5.10). Primary distribution was considered especially important in the retail sector. One of the representatives explained: *“retailers need buffer stock and it is more economical and efficient in terms of distribution to have it in one place. That is why primary distribution is growing”*. This was expected to continue in the future.

The rapid growth of e-commerce may have two effects, depending on the nature of goods being traded online. In the case of new products (forward channels), it is likely to eliminate some stages in the traditional structure of the supply chain. When second-hand goods are offered for re-sale or new products are returned (reverse channels), the number of links increases as products are shipped back to an intermediary, where they may be remanufactured, refurbished or repacked and then send to the customer. Hence, the overall impact of e-commerce on handling factor is difficult to predict.

Increasing costs of transport resulting from the possible road charging schemes, higher fuel prices, along with worsening congestion and tightening working time regulations, are also likely to result in more decentralised distribution structures with goods being handled multiple times while they pass along the supply chain.

On the other hand, in the retail sector the recent trend of importing products ready sorted for shops makes it possible for them to bypass the distribution centre and travel directly to retail units (DC bypass strategy). This reduces the number of times the goods are being handled as they pass along the chain.

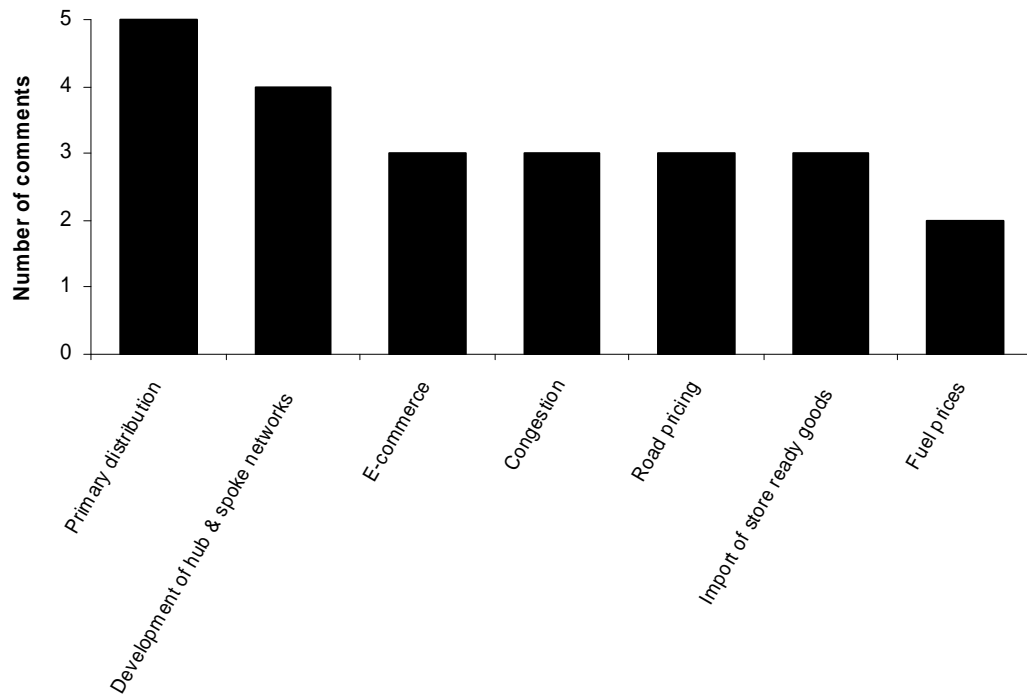


Figure 5.10. Factors influencing handling factor

Another point raised concerned the need for multiple handling of loads if non-road transport modes were to gain a significant share of the freight market, i.e. intermodal transport involves insertion of extra road feeder movements. The development of reverse logistics practices also increases handling factor as waste and recyclables are collected, sorted and consolidated before being sent for reuse, remanufacturing or final disposal. Changes in product mix resulting in more complex production processes as well as vertical disintegration of production and outsourcing may also add extra links into supply chains.

Average length of haul

Similarly to handling factor, average length of haul will also be a subject to contradicting pressures. The participants predicted that recent changes in customers' environmental awareness will support more local sourcing of products, particularly in the food sector. One of the focus group contributors called this "a farmers' market trend". It was also felt that the supply chains in the UK have now reached their maximum degree of centralisation and we will observe a pressure to decentralise operations in the future. As a result, even more hub-and-spoke types of networks are likely to develop. Also, primary consolidation of supplies to manufacturing plants or

retailers' distribution centres is gaining in importance, increasing the number of links in the supply chains but reducing the average distance between them.

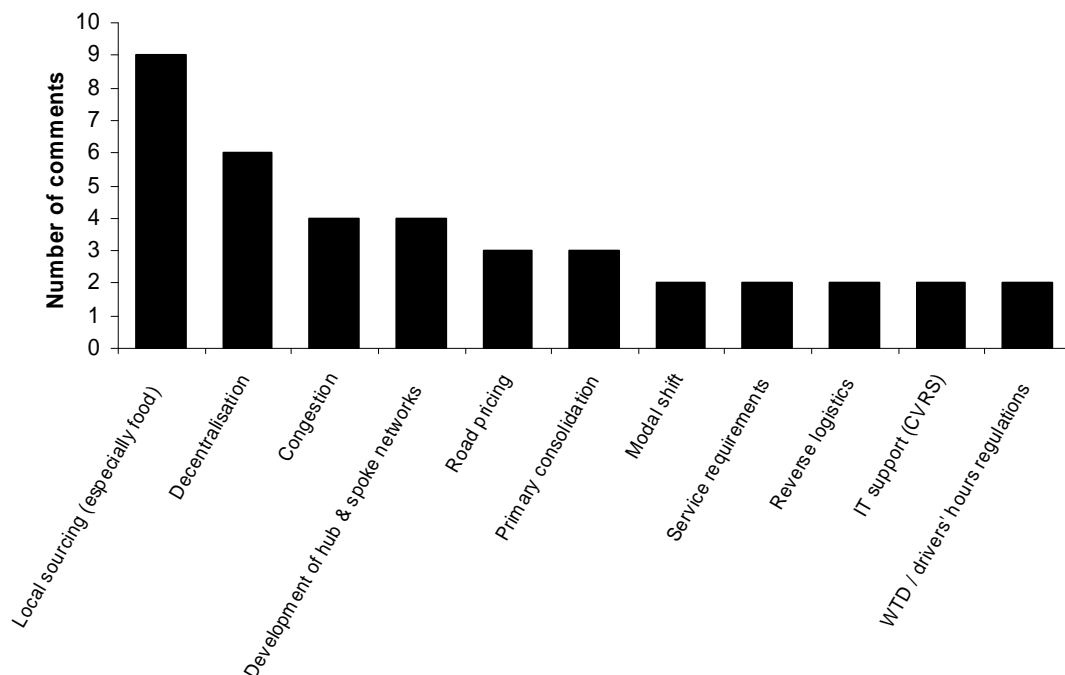


Figure 5.11. Main factors influencing average length of haul

Worsening congestion and the introduction of road pricing were perceived as unavoidable elements of the road transport system in the future. A positive consequence of these developments is an enhanced motivation to reduce the distance the goods travel in order to minimise overall distribution costs. Modal shift may influence the average length of haul in two ways. As goods are being shipped into / within the UK on bigger vessels able to access only the larger hub ports, their hinterlands will extend and goods will be transported over longer distances to get to their destinations. However, within the country, longer hauls are more likely to be transferred onto alternative modes. Thus, one longer journey by road will be substituted by a rail / waterborne transport link with shorter feeder movements by road on its both ends. This significantly reduces the average length of haul by road but increases the number of times goods are being handled as they move along the chain.

Also, service requirements are likely to limit the length of haul. Most companies have established service quality targets and this restricts the maximum distance between their production or distribution facilities and the customer base. IT support, particularly

CVRS technology, working time legislation, and increasing fuel prices are likely to further reduce the distance that freight travels. Conversely, increasing importance of reverse logistics may result in longer freight movements as waste products are shipped to centralised recycling, remanufacturing or energy recovery facilities, rather than to local landfill sites.

It was also suspected that a changing mix of commodities transported by road may have an impact on the average length of haul. With increasing proportion of foodstuffs and miscellaneous products in the total volumes transported, the impact of distance over which loads from these commodity groups typically travel may influence the overall figure. The average length of haul for miscellaneous products peaked in 1999 and since then it has been declining steadily. The average distance travelled by loads made up of food, drink and tobacco reached 129 kilometres in 2001. Although there has been a decline since then, the average length of haul for foodstuffs increased again in 2007. The average distance travelled for chemical goods has been declining gradually since 2002, whereas it has been relatively stable for bulk commodities in last five years (Figure 5.12). Overall, the relationship between changes in average length of haul at a commodity group level and the overall average distance travelled by HGVs is not straightforward. Thus, it is very difficult to predict if changes in commodity mix transported by road are going to have a significant impact on the average length of haul and what would be the direction of such an impact.

Further improvements in road infrastructure are likely to make road transport faster and more reliable. This may partly reverse the negative effects of congestion and encourage longer hauls. Average length of haul will also rise if goods purchased online are sourced from further afield and shipped from centralised distribution facilities. One of the participants suspected also that with increasing penetration of the UK road haulage market by non-UK registered operators some shippers decide to use foreign carriers on longer hauls to take advantage of lower prices they offer. These longer journeys do not get recorded in the CSRGT leading to shortening of the average distance travelled published in the official statistics.

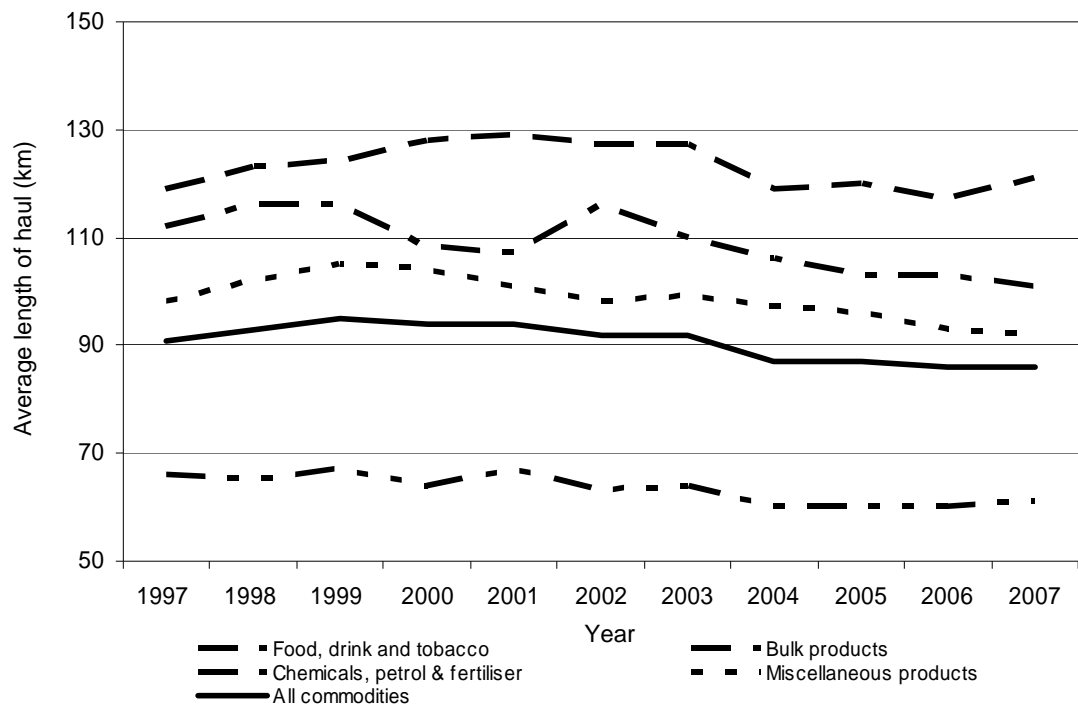


Figure 5.12. Average length of haul by commodity group
Source: Department for Transport, 2009a

All factors influencing supply chain structure are closely inter-related and it is difficult to isolate separate causes or predict an aggregate effect of the future changes in these. However, factors potentially leading to an increase in the handling factor and a reduction of the average length of haul seem to be prevalent. This confirms the initial view that decentralisation forces are on the increase and more regionalised supply chain structures are likely to emerge in the future.

5.2.3. Modal Split

At the moment the majority of freight in the UK is transported by road. In its Sustainable Distribution paper and subsequent policy statements the government has declared its aspirations to divert freight traffic to the more sustainable transport modes (DETR, 1999). The possible change in freight volumes transported by rail and waterborne transport was discussed at the meetings. The share of pipeline and air cargo was not considered due to the relatively low share of these modes and the specific characteristics of the goods carried.

Rail

Generally, the share of rail transport was expected not to increase significantly if BAU trends are considered. The participants felt that rail transport is more suitable for

particular types of products, i.e. bulk, lower value or long shelf-life goods transported over long distances. Waste and recyclables were also mentioned here. Rail freight transport was not perceived by most delegates as an appropriate logistics solution in current just-in-time oriented business environment. It was generally agreed that, at present, rail does not offer solutions for higher margin traffic and if these are not introduced soon, the share of rail will remain at the current level or even decline.

Secondly, the participants identified problems with rail infrastructure, particularly its insufficient capacity, as something that needs to be corrected if railway companies would like to capture more of the cargo market. The low loading gauge on the UK rail network was identified as a serious constraint. As infrastructure is shared with passenger trains and quite congested already, it was also felt that there is not enough capacity to significantly increase the amount of goods moved by rail. Investment in new infrastructure, possibly in dedicated freight lanes would be a preferred solution.

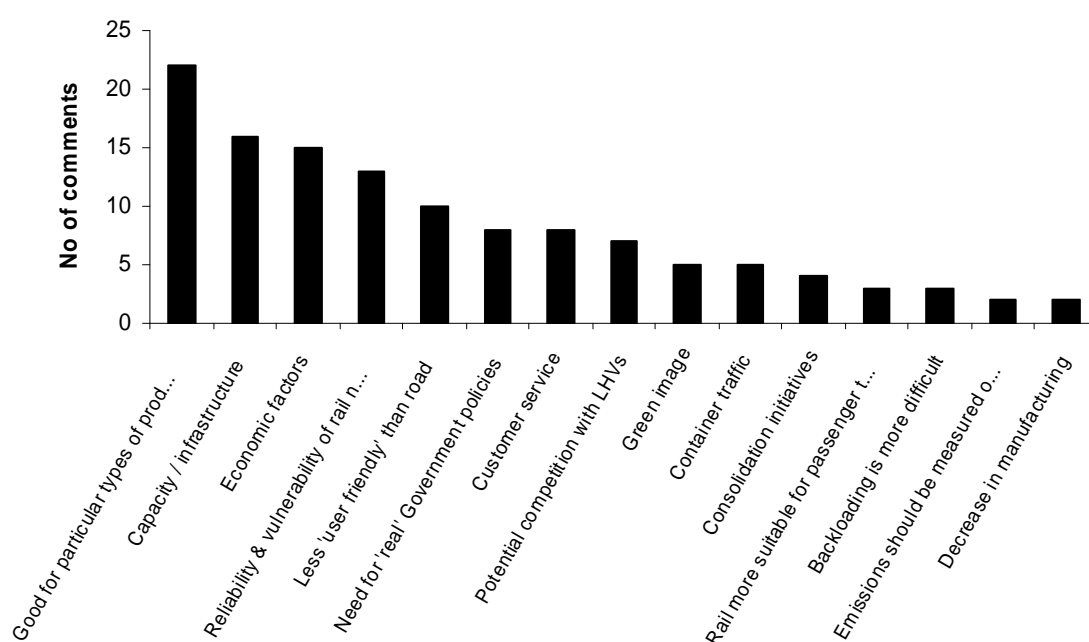


Figure 5.13. Factors influencing modal split - rail

Economic factors were the third most frequently listed determinant of a rail transport's share of freight market. Also, pricing structure and high barriers of entry were believed to inhibit the growth of the sector, with comments like *"700 kilometres is the minimum distance when rail becomes economical. UK is not big enough to benefit from the rail transport"* or *"Sending a load over 600 miles is only 5% more expensive than over 30*

miles. It is a very flat pricing structure” being raised frequently. However, if the costs of road transport were to increase significantly in the future, giving rail a real economic advantage, its share would go up. Such an increase is quite likely as a result of raising fuel prices, more severe congestion of the road network, introduction of road and/or congestion charging schemes or carbon trading initiatives.

Reliability and vulnerability of the rail network were also identified as important obstacles to the use of rail transport. The railway network is perceived as prone to technical problems, weather-related disruptions, unexpected delays or cancellations. This is further exacerbated by the fact that in case of any disruptions passenger trains always get priority. Channel Tunnel is seen a risky bottleneck that can easily cause disruption for international rail freight movements. Although it was generally agreed that rail is reliable and punctual when everything works well, the risk of unforeseen circumstances is high. Moreover, the consequences of having one freight-train worth of cargo held up are usually much greater than in the case of one delayed truck load.

Rail is also perceived as a less ‘user friendly’ mode than road. It requires more load handling, management efforts and increases labour costs. As not many business facilities are rail-connected, usually extra feeder movements by truck are necessary to transport cargo to/from railheads. When many loads are delivered at the same time, congestion around the railhead may be a problem. Then additional handling is essential to transfer loads onto/from rail wagons. Feeder movements add extra miles to the total distance travelled and the train route itself can often be circuitous. As a consequence, rail is often unable to provide a competitive service in terms of both cost and lead time.

The participants agreed that current market forces are unlikely to result in a significant mode shift and well planned government intervention would be necessary to move more freight onto rail. One of the invitees so summarised the current situation: *“The Government has aspirations but poor policies”*. Freight Facilities Grant scheme was given as an example of a positive initiative but it was felt that more needs to be done to encourage businesses to switch their cargo flows to rail.

Quality of customer service was also identified as one of the weak points of railway companies. They are seen as lacking customer focus and strongly oriented towards technical aspects of running trains rather than towards providing solutions aiming to

maximise rail's share of the cargo market. There were examples of difficulties in finding contact details of sales departments for rail and long waiting times to obtain a quote. Further, shippers require a door-to-door service, whereas railway companies take ownership of train haul only. Similar experiences are quoted in a report published by Scottish Executive (2007). Rail was nevertheless seen by the majority of delegates as a growth area in the freight transport market. Many felt that there would be a demand for more logistics operators to focus on intermodal transport and cooperate with railway companies.

Furthermore, possible introduction of Longer and Heavier Vehicles (LHVs) would be likely to erode freight traffic from other modes, particularly from the rail network. Improving the relative cost competitiveness of road freight transport combined with the greater flexibility and service level offered is likely to result in more companies moving freight by road. During the period these focus group discussions were being conducted, an investigation commissioned by the Department for Transport into the implications of allowing LHVs on the UK roads was also underway. Since then, it has been decided that LHVs are not going to be approved in the UK (although a longer semi-trailer option is still being considered), which makes this part of the focus group discussion less relevant.

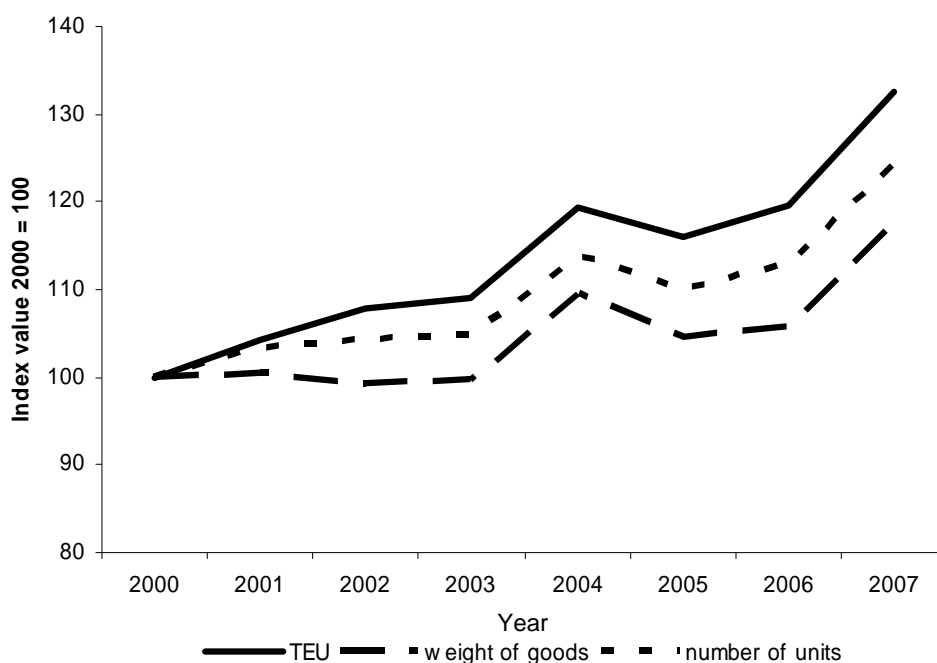


Figure 5.14. Container traffic in the UK
Source: Department for Transport 2008f

The steep growth in container movements to / from the ports offered the potential to increase rail's share of the freight market (Figure 5.14). It is also easier to ensure a balanced traffic flow in both directions, as there is a need to ship empty units back due to the imbalance in containerised import and export volumes. Empty containers made up 52% of all outward container movements in 2007 (Department for Transport, 2008f). Container traffic from/to ports seems to be particularly suitable for rail because it comprises relatively regular, high volumes on fixed routes. This would also result in additional benefit of alleviating congestion on the road network around the ports.

One way to make the use of rail more viable for companies not having sufficient volumes at present would be to encourage some sort of consolidation initiatives. However, this would require involvement of companies shipping goods to/from similar locations and having sufficient volumes to fill up a freight train on a regular basis. Such an initiative would be possible if it could offer an economic benefit to those taking part. However, it was felt that with the current pricing structure this is unlikely. Backloading of the trains could also be a problem. Additionally, companies would need to take the speculative risk of not having enough volume, and be prepared to pay for running the train whether loaded or empty.

Green image and environmental credentials were mentioned as reasons why companies may be willing to transfer more freight traffic onto rail in the future. There were also opinions that retailers with strong environmental strategies may put more pressure on their suppliers to use alternative transport modes. However, it was also argued that in order to assess the true environmental consequences of switching freight transport to rail, emissions from load movements should be measured on a door-to door basis, i.e. including necessary feeder links to / from railheads.

Further, in using rail, customer is usually expected to pay for a round trip or to find suitable backloads, which for freight trains is more difficult than in the case of HGVs. This also links to a previous point, i.e. to a need to assess the benefits from switching to alternative transport modes on a fully comparable basis. As one of the participants summarised: *"Because the UK is a short-haul country, there is a fine line between efficient lorry movement with the maximum payload, with minimum miles between the source and destination and backhauls, and rail transport with its requirement for additional handling and the inbuilt inefficiency compensated by the fact that long haul*

is more efficient in terms of the costs and environmental performance. If we have efficient lorry movements, it would be a shame to make them inefficient by the overall transfer to rail. Rail and road should work together on the route optimisation in order to reach the absolute peak of efficiency. There is definitely more to do on that”.

There were points raised that in a short-haul country like the UK, rail is more suitable for passenger traffic. Thus, transport policies should focus on diverting passenger travel, especially every-day commuting, from road to rail. This would greatly relieve congestion and free up road space for more efficient freight movements by trucks, reducing the environmental impact of road freight and passenger transport at the same time.

A short supply of freight wagons, long lead times when ordering new rolling stock, as well as problems with availability of train drivers were also said to limit the potential for rail freight traffic growth.

On the other hand, advocates of rail freight transport perceive train as ‘a moving warehouse’, which can cut company’s warehousing expenditure. As, in the freight market, railways compete with waterborne transport modes for the same types of loads, this could limit the growth of rail freight sector in the future. Load security concerns, if high value goods were to be distributed by rail, were also expressed.

It was noticeable that the companies which currently use rail services, especially on a dedicated train basis, had more positive attitudes towards rail than the others. This could suggest that the actual services are better than many non-users or past users of rail perceive. Thus, apart from introducing some of the measures discussed above, it would be beneficial to focus also on the improvement of this perception and promotion of rail freight services as ‘user friendly’ and customer-oriented.

Waterborne transport

Participants generally saw greater potential for the expansion of waterborne transport than for rail. Particularly, the development of short-sea routes like the coastal ro-ro services and increase in feeder movements from/to the deep sea ports were perceived as factors supporting the growth of waterborne transport. As vessel sizes increase, the largest cargo ships are not able to dock at smaller ports anymore. Thus, instead of

moving cargo by surface transport from the biggest ports, adding to local congestion and increasing GHG emissions, a short-sea/coastal movement may be employed to transfer goods to the local port closest to their final destination.

It was also agreed that waterborne transport has a fair share of the freight market and it is particularly suitable for certain types of cargo. As it is a rather slow mode, it is good to transport bulk raw materials like for instance coal, gravel or ores, low value, long shelf-life products, waste, recyclables, etc. New coastal routes operated by faster ferries would need to be opened to attract higher-value freight traffic. However, this process may be constrained by the insufficient capacity of ports which currently suffer from congestion. The participants expressed their concerns that particularly the main ports would not be able to handle additional traffic efficiently, if volumes of cargo were to increase significantly. Thus, port capacity may be an obstacle to developing reliable logistics solutions involving inland, coastal or short-sea shipping.

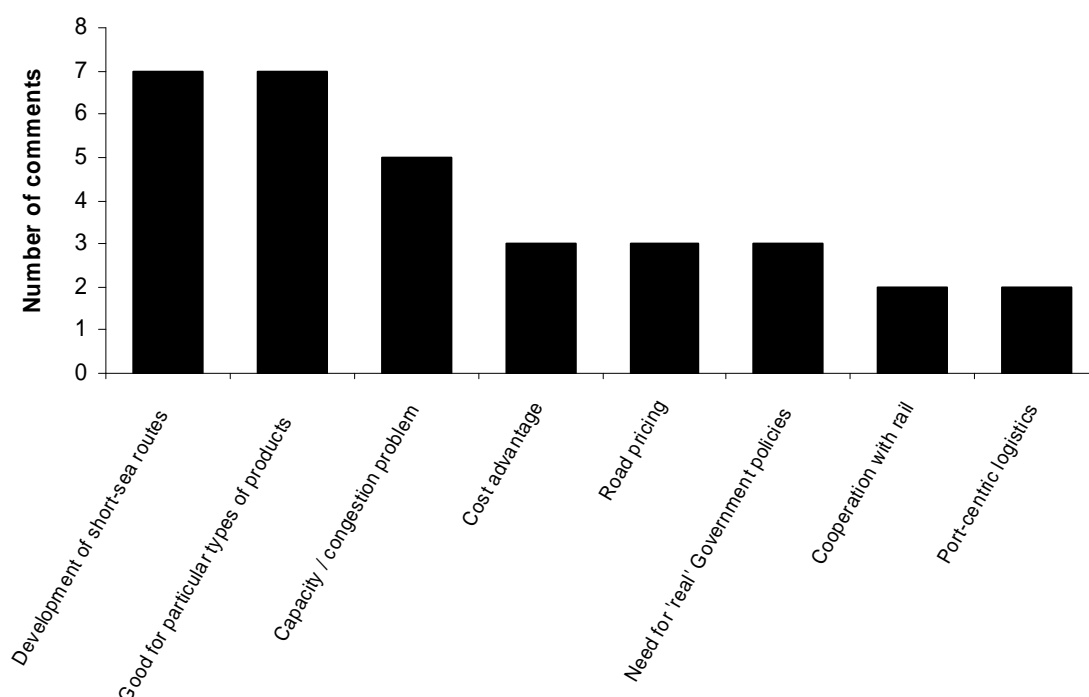


Figure 5.15. Factors influencing modal split – waterborne transport

Additionally, at present waterborne transport has a significant cost advantage over the other modes per tonne-km. It makes it particularly attractive for the low value cargo market, but it may also be a significant factor in attracting companies transporting large

volumes of higher-margin goods. This advantage will increase even further if the Government decides to introduce road pricing or impose more taxes on the road users.

As in the case of rail, the participants agreed that new, well planned government policy measures are necessary, if the share of waterborne transport was to increase significantly. The Waterborne Freight Grant scheme was mentioned as a good example of policy aiming to encourage more use of waterborne transport.

The potential for a further increase of non-road modes' share of freight market could be enhanced by closer cooperation between waterborne transport and rail. Container traffic was one example where such solution would be likely to attract new users, especially due to the two-way nature of its flow. Containers could be shipped from a deep-sea to a local port and then transported by rail to a distribution centre and then back again. However, an initiative like this requires presence of a market player who has sufficient resources, knowledge and experience and would be prepared to bear the risk of coordinating the operation.

The development of port-centric logistics with more value-adding services offered by port operators should attract even more freight traffic. Locating a distribution centre at a port eliminates the need of moving containers inland and returning them empty, leading to significant cost savings and environmental performance improvement. Further, it was estimated that container utilisation can be improved by up to 40% if containers are emptied at the port and do not need to be transported inland so that the weight restrictions on the road network do not apply (Mangan et al., 2008). Potential benefits of locating a distribution centre near the port combined with cost advantage of waterborne transport are likely to result in the further uptake in waterborne freight services.

There were also critical opinions of customer service quality provided by port operators. It was suggested that some ports are badly managed and thus underutilised. According to one of the invitees, poor management is the reason for alleged capacity problems, while in fact enough infrastructure is in place already and more cargo could be handled with the available resources.

One person pointed out that the initiatives aiming to increase the amount of freight traffic moved by waterborne transport modes may result in diverting some of the traffic not only from road but also from rail. This is because railways target similar types of goods flows. Hence, future policies promoting the use of waterborne transport should be aimed at road users in order to avoid increasing the share of waterborne transport at the expense of rail.

There were also concerns about the extra miles and handling required to transport loads to/from ports. Coastal shipping is not attractive when points of origin and destination are too far away from the port. Further, not all companies handle sufficient volumes to benefit from switching to waterborne transport. Consolidation initiatives and grouping of loads could help to build up large enough volumes to justify the use of coastal shipping. A timber consolidation centre in Scotland was quoted as an example of such an initiative.

5.2.4. Vehicle Utilisation

Vehicle utilisation is determined by two variables: empty running and lading factor. Empty running is the proportion of total vehicle kilometres run empty. The lading factor is defined as ‘the ratio of the tonne-kilometres that a vehicle actually carries to the tonne-kilometres it could have carried if it was running at its maximum gross weight’ (Department for Transport, 2009a, p.42).

Empty running

Invitees argued that the direction and scale of changes in the empty running figure was difficult to predict. The EU Working Time Directive and domestic drivers’ hours regulations applicable to HGV drivers were frequently listed as major reasons why empty running may increase in the foreseeable future. With a limited number of hours a driver can be on duty, there is less scope and flexibility for picking up a load on the return journey. On the other hand, rising costs of transport were considered to be the main factor pushing the empty running figure down. As running an empty vehicle becomes increasingly expensive, companies are more incentivised to find backloads. Further, advances in information technology like telematics systems are helping managers to improve the utilisation of their fleets. The ability to track the movements of vehicles allows dynamic fleet management and more responsive route planning minimising the distance travelled and/or making backloading easier.

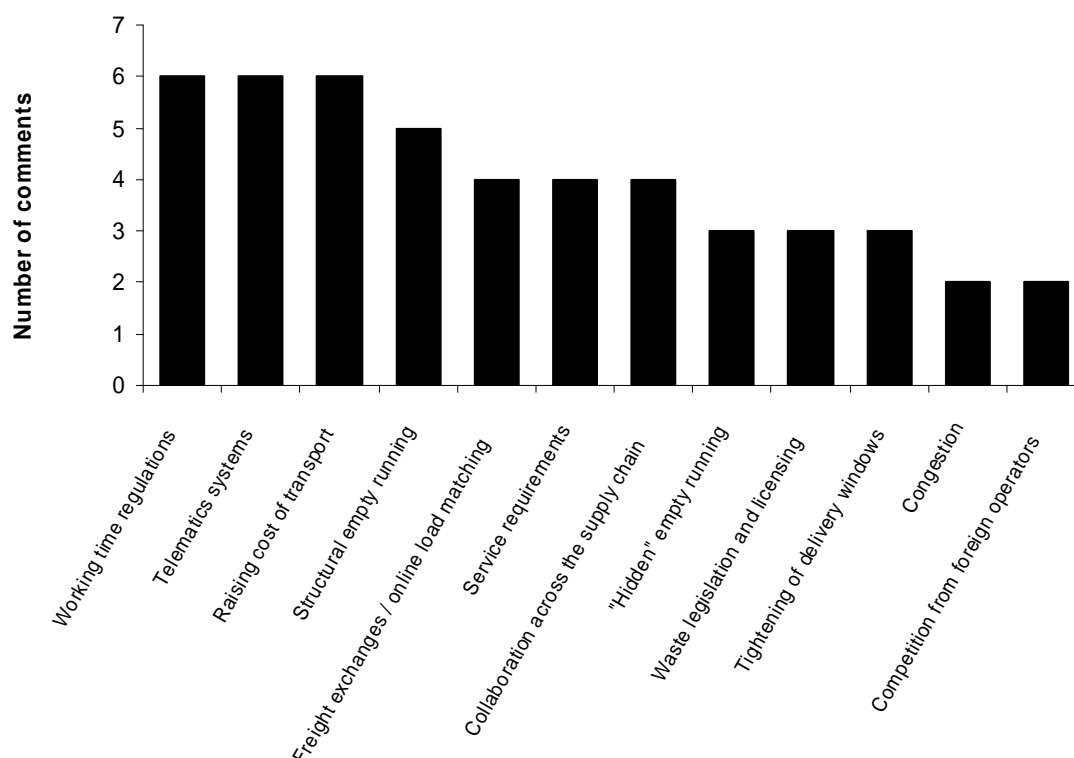


Figure 5.16. Factors influencing empty running

Meanwhile, regional imbalances in freight flows, incompatibility of vehicles and loads or scheduling constraints make it more difficult for the companies to avoid running empty trucks. It was frequently emphasised that a substantial percentage of the empty running is ‘structural’ and thus virtually impossible to eliminate. Hence, the proportion of empty running cannot fall below a certain level. It was generally agreed that current situation is close to this minimum level. The issue of ‘hidden’ empty running where the empty containers or empty handling equipment are classed as a load was also highlighted. Hence, the expected future growth in the container traffic may worsen the problem of empty running, although this will not be mirrored in official statistics.

Uptake in freight exchanges and load matching services may bring further reductions in the percentage of kilometres run empty. They make it easier for an operator to find suitable backload by providing a wider pool of potential consignments, simplifying communication between shipper and carrier as well as saving time and resources involved. Case studies from companies facilitating online trading of freight capacity suggest that their clients have achieved significant improvements in fleet utilisation (Mansell, 2001). If online freight trading platforms take off in the future, the benefits may become visible also on a macro-scale.

For many companies, customer service requirements are much more important than transport costs. This is particularly true for higher-margin products. In such a case, priority may be given to onward loads. Hence, backloading may not even be considered due to the risk of a vehicle not returning on time and thus failing to meet the requirements of an outbound customer (McKinnon and Ge, 2006). The participants also believed that closer collaboration amongst the supply chain members offers a potential of bringing the percentage of empty travel down. Better integration and visibility of transport costs along the chain gives partners a better incentive to improve utilisation of their fleets.

Waste legislation and licensing rules were identified as factors that could contribute to lowering of the empty running figure. At present, waste carriers must be registered with the Environmental Agency and carrying waste without the relevant authorisation is an offence. One of the participants said: *“Waste legislation is important here. One of the big elements of empty running must be small vehicles running on the multiple-drop rounds. They do not have anything to take back. If the waste legislation was changed to allow them to carry the recyclables from anybody they deliver to, that would lower the empty running figure and improve the loading factor”*.

The participants also listed tightening of delivery windows, particularly at retailers' distribution centres, as one of the factors that may discourage transport managers from trying to find backloads for the vehicles to carry. As shortening periods when a delivery can be made increase the risk of a load not being accepted at the destination, companies are not likely to take the risk that a vehicle needed for an onward delivery can be held up with a backload. Also, if a delivery window is missed, the driver may be forced to wait until all other incoming vehicles are unloaded before his/her consignment is accepted. This, in turn, may make picking up a backload impossible.

Also, more severe and frequent congestion incidents on the road network are likely to result in more failed backloads, according to the invitees. Congestion (measured as seconds lost per vehicle kilometre relative to free flow speeds) is expected to rise by about 37% between 2003 and 2025, resulting in an average increase in time spent travelling of 6% or 4 seconds for each kilometre travelled (Department for Transport, 2008e). This may have a significant negative effect on the empty running figure.

There were also opinions that the blame for a recent increase in the empty running figure can be put on competition from foreign hauliers. According the participants who raised this point, foreign-registered carriers coming with an inward load to the UK offer cheaper rates on loads they are willing to carry on their return journey. Also, the activity of foreign hauliers is not covered by the empty running statistics.

Other issues mentioned included failed backloads due to inward pallets not being accepted at a customer's DC and an increase in frequency of night-time deliveries. Transport on non-congested roads at night is more reliable and fuel efficient. However, it may make picking-up a backload impossible because not all companies operate their distribution facilities on a 24/7 basis. It was also suggested that flattening of the empty running trend may be related to the recent decline in the average length of haul. With vehicles travelling over shorter distances, there is less incentive to find backloads. Backloading a vehicle usually adds complexity to the system and may require some diversion from the original route. Thus, benefits of carrying backloads over shorter distances may not be significant enough to offset the additional efforts and resources needed to do so.

The overall impact of the factors discussed was regarded as highly uncertain. The effects of some of the factors are superimposed magnifying their effect, for example tightening delivery windows, congestion and service requirements, whereas some impose conflicting pressures on the empty running figure. On average, the experts predicted that empty running would most likely remain relatively stable in the foreseeable future.

Lading factor

The most frequent point raised on the lading factor theme regarded development of consolidation / collaboration initiatives within supply chains. It was strongly believed that such practices will become more common in the future, helping companies to maintain a high level of vehicle fill. This is one of the ways shippers can deal with still strong just-in-time (JIT) pressures and the requirement to minimise the inventory levels across supply chains. The widely adapted JIT practices, especially when combined with tight delivery windows, were listed as a most frequent reason for impaired lading factor.

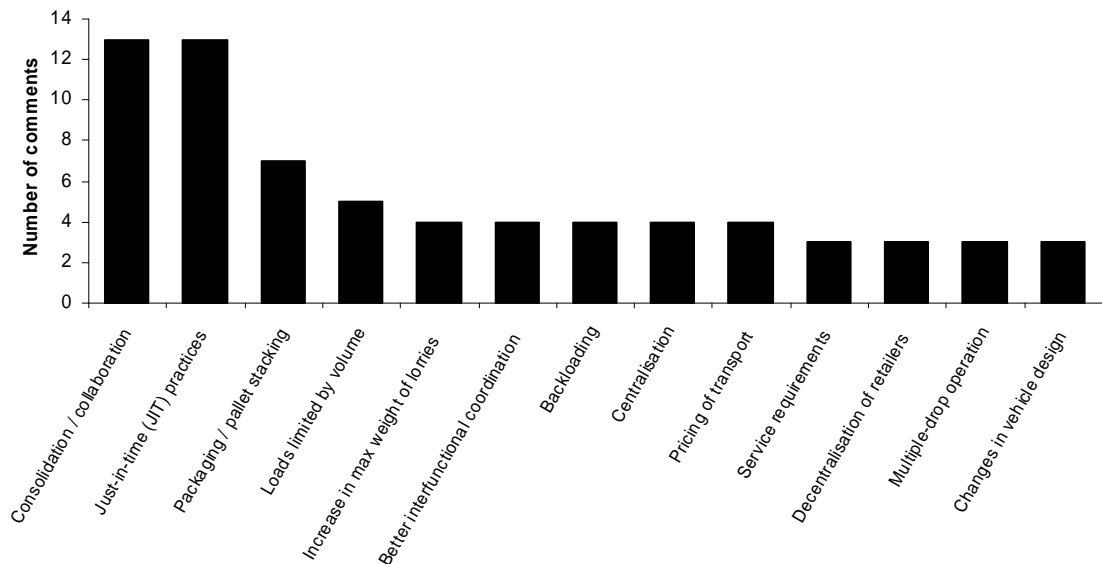


Figure 5.17. Factors influencing vehicle loading

Furthermore, in the marketplace dominated by the big retailers, the suppliers have to accept the delivery demands of the more powerful partners, often compromising vehicle utilisation. Retailers expect not only smaller and more frequent deliveries, but also increasingly demand products to be delivered in shelf-ready packaging. Shelf-ready packaging minimises the amount of handling needed in a store but it tends to be weaker and more fragile than standard packaging. As a result, it usually impairs pallet stacking and vehicle loading (for example fewer cases can be stacked on a pallet or pallets cannot be double-stacked on a vehicle).

Attention was also drawn to the fact that lading factor is a weight-based ratio. It is often the case that fully loaded vehicle in terms of volume is only partially loaded in terms of weight, which can give a misleading impression of the real level of vehicle utilisation. As increasing proportion of loads is volume limited (Department for Transport, 2009a), this may falsely lower the average lading ratio. The participants emphasised the need to measure the lading factor not only in terms of weight but also in terms of volume carried. Further, it was suspected that an increase in the maximum permissible weight of lorries from 41 to 44 tonnes gvw in February 2001 might have resulted in a temporary drop in the lading factor. After the new weight limit was introduced, more vehicles have been plated at 44 tonnes but companies have not adjusted their operating practices straight away, hence the greater likelihood of a HGV not running at its full capacity. A review by McKinnon (2005) confirms these speculations. He notes that by the end of 2003 more than a half (52%) of HGVs with 38 or more gvw were already licensed to

operate at 44 tonnes. However, in the same year these vehicles were filled to their maximum capacity on approximately 22% of the distance that they travelled loaded, and their average load of 17.9 tonnes (instead of the maximum of 29 tonnes) could comfortably be carried on a vehicle plated at 38 tonnes (McKinnon, 2005). If LHVs were to be introduced in the future, average lading factor might drop by an even greater margin, despite the fact that the degree of load consolidation would increase. However, the temporary character of a likely decline in the lading factor in such a case was strongly emphasised by the invitees.

A move away from the traditional functional structures and better coordination of internal operations within companies, supported by for example Enterprise Resource Planning (EPR) systems, were believed to help transport managers to ensure better utilisation of their fleets. Integrated planning for manufacturing and logistics supports companies' efforts to despatch products in full-truck loads and helps to optimise transport operations. Also, centralisation of production and distribution facilities both within a company and / or across the supply chain, allows more efficient loading of lorries. Instead of a few partial loads to a number of destinations, one consolidated order is sent to a centralised facility. However, better loading may be offset by the potentially longer haul required to deliver the goods to one central location. Although a centralisation trend may improve the lading factor on a macro-scale, the impact on an individual company can be more complex. Conversely, the recent signs of decentralisation pressures, particularly amongst retailers, may impair the lading factor in the future.

The participants' experience also suggested that, although backloading can significantly reduce empty running, at the same time it may have a negative impact on the lading factor as lower utilisation is usually achieved on the return journey. This is partly because a substantial proportion of backloads comprises empty handling equipment (for instance roll cages or plastic baskets), and thus significantly underutilises vehicle capacity in terms of maximum payload weight. As an increasing proportion of packaging materials and handling equipment within the supply chain is recycled or reused, this may lower the lading factor. At the macro-scale, however, a range of other environmental benefits may be achieved, through reduced demand for virgin materials, less energy used to produce new packaging, and less waste being sent to landfill or incineration facilities.

The traditional pricing system for transport services where a shipper is given a standard quote for a load may adversely affect the level of vehicle utilisation. A use of different rates depending on the degree of loading would improve the situation and help to maintain a high level of vehicle fill. In addition, the increasing average value density of goods offered is making logistics more service-driven than cost-driven and companies are often prepared to sacrifice optimum loading of vehicles in order to satisfy their customers' requirements. One of the shippers explained: "for us it is the service not the cost that drives the business" and the majority of the participants agreed that this approach is representative of many organisations.

Increase in the incidence of multi-drop operations was also listed as one of the factors contributing to a recent decline in the average loading of trucks. As sectors associated with multi-drop deliveries (for example pallet or parcel services) are expected to experience a major growth in the forthcoming years (Transport Intelligence, 2007), this may contribute to further impairments in vehicle utilisation.

The participants noted also that changes in vehicle design, especially double-deck or high-cube trailers, may help to increase average payload weight where volume of goods is a limiting factor. In the UK, companies may take advantage of the high bridge and tunnel clearances and expand the vertical dimension of trailers (McKinnon, 2007b). Thus, with diminishing average density of loads, double-deck or high-cube solutions are becoming increasingly popular (McKinnon and Campbell, 1997) and case studies confirm that they may bring significant improvements in vehicle utilisation (Freight Best Practice, 2007h).

Increasing congestion, apart from being likely to increase empty running in the future, was also expected to have a negative impact on vehicle loading. At some point in the future, traffic conditions may worsen so much, that multi-drop rounds may become too time consuming and a company will be forced to dispatch more partially loaded HGVs in order to service the customer base within the required time frame.

Wider adaptation of the postponement principle was identified as a means of improving vehicle utilization and ensuring more efficient transport. Keeping goods in a generic form and/or in a single location helps transport operators to load their trucks more efficiently, leading to an overall increase in the lading factor.

As mentioned before, fuel prices are expected to significantly increase in the future. This will result in higher transport costs, thus giving companies greater incentive to maximize utilisation of their fleets. Right-sizing of the vehicle fleet to a company's transport needs was also identified as a way to ensure optimum loading. Some businesses tend to invest in larger trucks than they actually need. They prefer to have spare 'safety' capacity in case the demand changes. This, however, implies sub-optimal loading in everyday operation. It was believed that more companies are now trying to 'right-size' and improve utilization of their fleets.

Two contradicting trends that may impact on the lading factor were identified in the retail sector. The reduction of stockroom space in stores is driving a need for smaller and more frequent deliveries, thus potentially impairing vehicle loading. On the other hand, some retailers have begun to reduce the number of store deliveries in order to eliminate back-door congestion and improve internal operations. It was difficult to predict which of the trends will be prevalent in the future.

In conclusion, as with the empty running figure, the participants were not expecting any significant changes to the lading factor of lorries.

5.2.5. Fuel Management

Two aspects of fuel management were discussed: fuel efficiency and carbon intensity of fuel. Fuel efficiency can be expressed in terms of vehicle kilometres per litre of fuel used and carbon intensity regards the amount of CO₂ emitted per litre of fuel burnt. The fuel management issue seemed to be the most problematic for the participants to discuss, especially the carbon intensity ratio. At the majority of the sessions, invitees indicated that they lacked the specific technical knowledge to be able to speculate on the future development of low carbon fuels. However, there was a consensus that there will be new developments in this area and carbon emissions per unit of fuel used can be further reduced.

Fuel efficiency

Driver training was believed to be the most effective means of further increasing fuel efficiency of trucks (Figure 5.18). It was emphasised that for training to be successful it needs to be repeated on a regular basis. The evidence from participants' organisations suggests that one-off initiatives tend to bring good but short-term results. Without

continuous monitoring and periodical training sessions the fuel efficiency gains diminish with time.

Telematics systems support monitoring of vehicle performance and driver behaviour help to eliminate unnecessary idling, ensure compliance with speed limits and help to ensure that vehicles are maintained in optimal condition. This can substantially reduce fuel consumption. Also, through real-time vehicle tracking, transport planners can respond to new orders as they are received, dispatching the closest available vehicle and minimising the total distance travelled. Real-time navigation helps to identify the fastest route to a destination, further reducing fuel consumption. Industry-wide implementation of telematics systems was expected by the participants in coming years. Telematics systems were also believed to one of the factors to offer the greatest potential to improve fuel efficiency in the future.

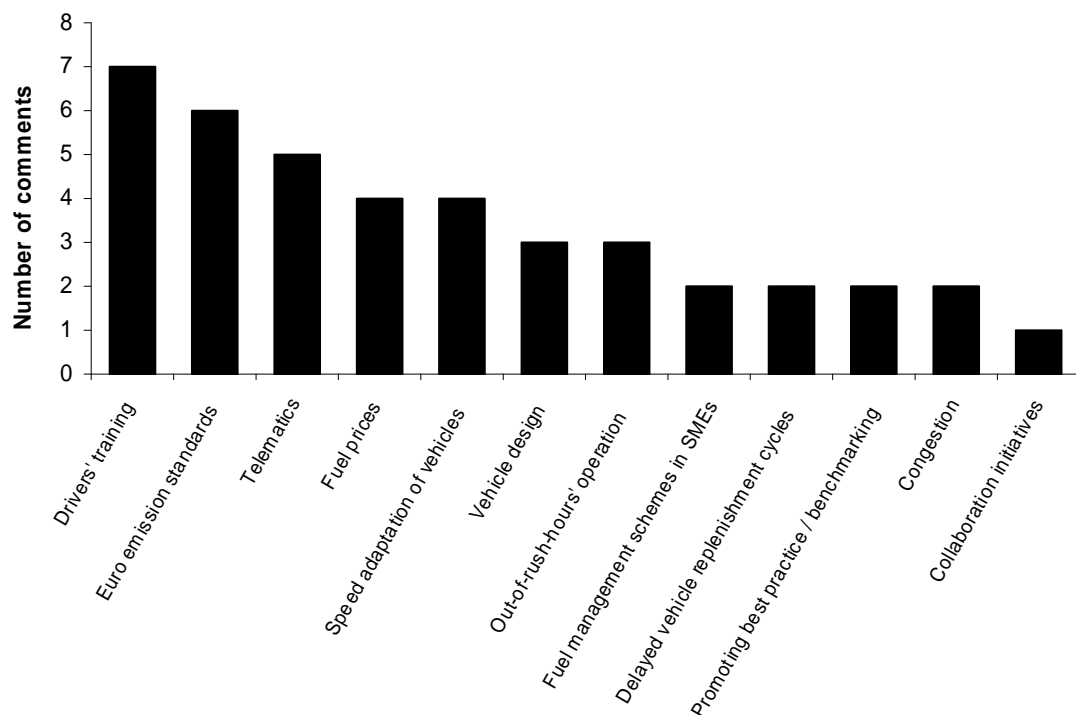


Figure 5.18. Factors influencing fuel efficiency.

On the contrary, one of the main inhibitors to improvements in fuel efficiency may be the trade-off between measures to alleviate different environmental impacts of road freight transport. Although the new environmentally friendly engines (Euro IV and Euro V) reduce emissions of some air pollutants, particularly NO_x and particulate matter, they can have an adverse effect on fuel consumption and thus on CO₂ emissions. With

the Euro VI emission standard planned to come into force in 2013 this problem may be exacerbated even further. However, participants strongly emphasised that rising fuel prices will reinforce companies' efforts to increase fuel efficiency.

Speed adaptation systems were also identified as offering an important fuel saving solution in the future. Large goods vehicles already have to be fitted with speed limiters. However, the currently mandated speed limiters are set to the national speed limit and do not respond to the actual limits on a vehicle's route. The next step will be the use of intelligent speed adaptation systems that can recognise vehicle type along with road category and impose the appropriate speed limits. A recent Intelligent Speed Adaptation (ISA) project commissioned by the Department for Transport has carried out an initial examination of speed adaptation technology for a goods vehicle. Although based on a very limited trial, the results suggest that ISA diminished speeding and led to a reduction in speed variation (Lai et al., 2007). As a result, excessive fuel consumption can be prevented and significant savings, both in terms of operating costs and CO₂ emissions, could be achieved.

Further fuel efficiency improvements are expected from changes in vehicle design. Aerodynamic styling involves adapting the shape of a truck in order to minimise the drag it creates as it moves through the air, resulting in lower fuel consumption of a vehicle. Even poor initial aerodynamic design can be substantially improved by using add-on aerodynamic features, like for instance cab roof fairing or tractor side panels (Freight Best Practice, 2007d,e). Recently, Marks & Spencer has achieved 10% fuel saving by switching from standard to aerodynamically shaped teardrop trailers (Don-Bur, 2009). It was believed further improvements in vehicle design are possible and will contribute to improving fuel efficiency of vehicle fleets in the future.

Furthermore, by altering their internal operations and initiatives like night-time delivery the companies are likely to improve their fuel consumption by avoiding congestion and taking advantage of smooth driving conditions. Although it was emphasised that changes in operating practices, particularly night-time delivery, are already becoming more common and this is going to intensify even further in the future, location of company's facilities, especially in residential areas, may be a serious limitation to wider application of these initiatives.

Dissemination of best practice and benchmarking were also considered to be important future sources of fuel efficiency improvements. It was also felt that large operators already have fuel management programmes in place and minimise their fuel consumption quite effectively. Efforts to promote ways to optimise fuel use should now be aimed at small and medium haulage companies, which often do not have sufficient knowledge or resources to implement fuel efficiency measures themselves. As 74% of operators in Great Britain own a fleet of 1 to 5 HGVs (Department for Transport, 2009a), this could lead to large fuel savings on a macro scale.

Lengthening of vehicle replenishment cycles will slow the rate of fuel efficiency improvement. Because of uncertainty as to whether road or congestion charges are going to be dependent on emission performance of a vehicle, companies may delay decision to purchase new trucks until new regulations are in place. Further, as mentioned above, emission standards aimed at reductions of local and regional air pollution may result in increased fuel consumption.

Worsening congestion on the road network is one more obstacle to fuel efficient operation. As much of the road network is reaching its maximum capacity, congestion becomes unavoidable and companies increasingly account for it in their everyday planning. The degree to which an individual company will be affected depends on the location of its facilities, operating times, technology available or possibility of using a diversion route, etc. However, it was predicted that congestion is going to worsen with time, potentially offsetting fuel efficiency gains achieved through other measures.

One of the participants also envisaged more collaboration initiatives, especially amongst smaller operators, aiming to use joint resources in order to purchase and operate more fuel efficient trucks. Through collaboration, groups of companies not only could invest in vehicles equipped with latest fuel efficiency solutions but also achieve better fleet utilisation leading to more efficient performance.

Carbon intensity of fuel

The discussion on the carbon intensity of fuel focussed mostly on issues regarding use of biodiesel in HGVs. The participants were primarily concerned about the availability of biodiesel supply. It was felt that the supply of biofuels may not be sufficient to satisfy the rising demand, especially with the increasing proportion of diesel-powered

passenger cars in the national fleet. The recent vehicle licensing data suggest that 25% of all licensed cars in GB were diesel propelled, twice the proportion of 10 years ago. Almost a half (43%) of cars and nearly all vans (98%) registered for the first time in 2008 were fuelled by diesel (Department for Transport, 2009f). The second most frequently expressed concern regarded the sustainability of biodiesel. The participants feared that increased demand for biofuel feedstocks may lead to accelerating damage to ecosystems. Replacing rainforests with single crop cultivation, which reduces biodiversity and may eventually accelerate GHG emissions, was one of the examples used to portray potential negative impacts of biofuel use. Also, a shift from agricultural to biofuel feedstock production could lead to increases in food prices, which is likely to affect mostly the already vulnerable developing countries. *“If we produce more biodiesel we will not be able to provide sufficient food supplies for the developing countries”* was one of the most frequent comments.

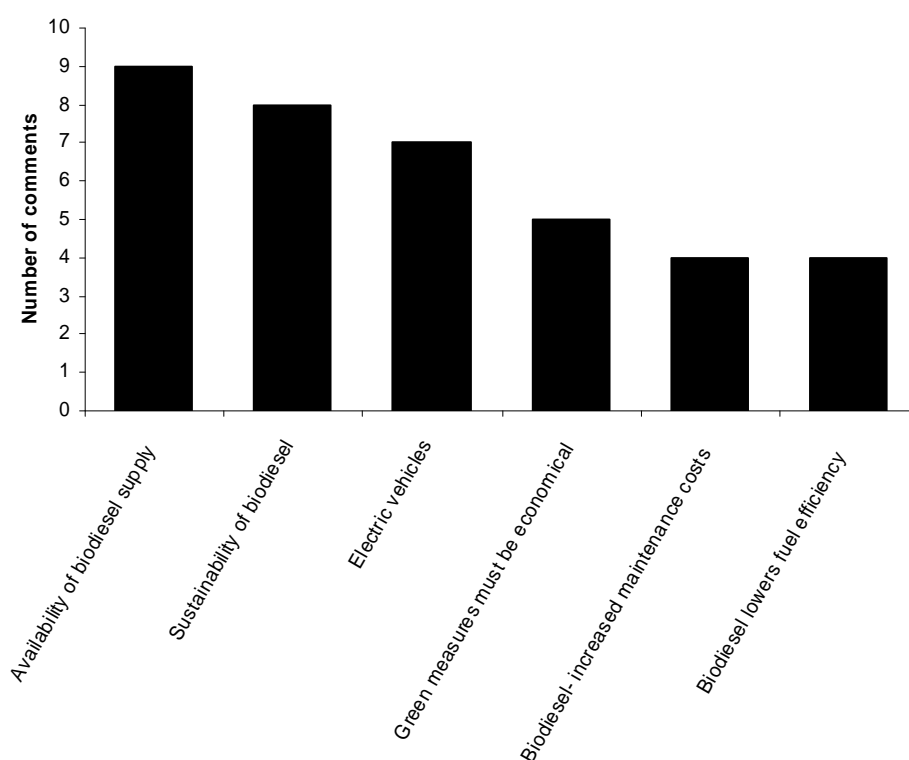


Figure 5.19. Factors influencing carbon intensity of road freight

Currently, on a global scale just 1% of cropland is occupied by feedstock for biofuels. However, it is expected that the rising world population, changing diets and demand for biofuels will increase demand for cropland by between 17% and 44% by 2020. Although there should be sufficient appropriate land available to 2020 to meet this

demand, the situation beyond 2020 is uncertain and in the long-term farming feedstocks for biofuel production may not be sustainable (The Gallagher Commission, 2008). Further, if biofuel production is significantly increased, this could force prices up. This is particularly relevant to the UK and rest of the Europe where there is less available land and more competition from urban development and food production (Department for Transport, 2006). In the UK, there are on average 92 million litres of biodiesel supplied to the market each month. 6% of this monthly total (5.5 million litres) is produced domestically. 86 million litres are imported every month, mostly from the US (36% of the UK biodiesel supply originates from there) (Renewable Fuels Agency, 2009). The Renewable Transport Fuel Obligation (RTFO) requires that a specified percentage of fuel supplied in the UK comprise biofuels. Recent amendment to the obligation sets the target of 3.25% (by volume) in 2009-2010, 3.5% in 2010-2011, 4.0% in 2011-2012, 4.5% in 2012-2013 and 5.0% thereafter. Thus, the amendment slows down the initial obligation on fuel suppliers that biofuels should make up 5% of UK road fuel sales from 2010/11 to 2013/14. (The Renewable Transport Fuel Obligations (Amendment) Order 2009, The Renewable Transport Fuel Obligations Order 2007). The reduction in the biofuel content targets is mostly based on recommendations of a report prepared by the Gallagher Commission for the Renewable Fuels Agency. The evidence gathered in the review did “not provide assurance of the sustainability of any particular level of target and the creation of a sustainable biofuels industry cannot be assured” (The Gallagher Commission, 2008, p.10).

Increased vehicle maintenance costs were one of further concerns regarding biodiesel use. The engine oil, oil and fuel filters in trucks run on biodiesel need to be changed more frequently. There were also concerns that some truck manufacturers will not honour the warranty if a blend of more than 5% biodiesel is used. Also, as energy content of biodiesel is around 10% less than that of conventional diesel, increased fuel consumption was identified as one of the main obstacles in switching biofuel. One of the participants admitted that the company he represents had trailed a 95% biodiesel blend over a 12-month period. Operating two trucks on it, they saw a fuel consumption increase by 10% and maintenance costs rise. It meant that even if the fuel duty for biodiesel was reduced by 20 pence per litre, operating costs would still increase by £5000 a year when compared to standard diesel. With the 20 pence per litre duty differential to cease from 2010 (HM Revenue & Customs, 2008), the cost of running a HGV fleet on biodiesel is likely to increase even more.

Electric vehicles were identified as having the greatest potential to reduce the carbon intensity of transport. They were believed to be of greatest significance in urban areas, initially. With the developments in battery technology in the future, they could be used in heavier vehicles on longer hauls as well. Electric vehicles were assessed as one of the most viable options to reduce carbon intensity of road transport, particularly because the infrastructure to distribute electricity already exists. However, carbon reduction potential in this case strongly depends on a mix of fuels used to generate electricity. The decision on fuel sources is mostly a result of the energy policy of a given country, thus, remains beyond the control of a corporate or individual user. One of the companies represented was involved in an electric trucks trial from the consolidation centre to retail units clustered in one shopping area. Although the trial was still ongoing, it seemed to be successful. This was mostly because the vehicles were used on a short, fixed route with multiple delivery points, which is currently the best application for electric vehicles at the current state of technology.

The participants also emphasised that green measures need to bring businesses a clear economic advantage. Otherwise, companies are unlikely to implement any of them, unless they are required by law to do so. Green image is important but it cannot have a negative impact on the bottom line. 'Green-gold' measures are always going to be favoured and prioritised by the companies and it was felt that any attempts to promote initiatives to reduce carbon intensity of transport operation should focus on them.

Wider use of compressed natural gas (CNG) powered trucks was also expected. CNG is a gaseous mixture of hydrocarbons consisting of 80% - 90% methane. As CNG contains less carbon than any other fossil fuel, less CO₂ is emitted per vehicle-kms travelled (Khare and Sharma, 2003). Another potential measure to reduce the carbon intensity of road freight transport in the future would be to use renewable biogas produced from organic waste to power the fleets. Hydrogen fuel cells were also identified as one of the ways to reduce carbon intensity of road freight transport.

5.3. Potential Limitations of the Research

The focus group discussions have identified a series of possible changes in key logistics parameters. However, data collected is qualitative and based on a limited number of

examples making it difficult to generalise to the total population of the UK logistics-related businesses.

The research methodology literature mentions several possible problems with focus group research. Firstly, people who attend the meetings are likely to represent a biased sample, as the efforts to engineer the attendance of the meetings to provide a cross-section of expertise and opinions are often only partially successful (New and Payne, 1995). In the case of this research the invitations had been sent out to a mix of experts from different supply chain-related backgrounds to ensure an optimal mix of professionals with certain characteristics in common but also sufficiently diverse to stimulate the discussion (Krueger, 1994, Greenbaum, 1998). Nevertheless, on average one in three participants did not show up at the event, even though they had indicated their intention to attend. As a result, the ‘retailers’ and ‘policy makers’ groups had the lowest turnout level with only five representatives, while the ‘manufacturers’ were the best represented group in the research (16 participants).

Another issue referred to frequently in the methodological studies shows how mix of participants cannot be fully controlled. The most charismatic and self-confident participants may consciously or unconsciously influence the opinions of the others dominating the discussion and leading to a “group think” syndrome (Bryman, 2004). There is also a risk of the discussion diverging from the original subject of investigation (Greenbaum 1998). In anticipation of these problems, the structure of the meetings was planned in advance and a formal presentation was used each time. The facilitator also intervened whenever necessary to keep the discussion on track.

The literature strongly emphasises the fact that focus groups cannot be used where quantitative data needs to be collected (Greenbaum 1998). Nevertheless, they can generate hypotheses that merit further quantitative investigation (Kreuger 1994). Hence, the focus group sessions were not designed to quantify the projected trends but to explore factors that may have an impact on these trends. They have only provided an indication of where the trends will head. In the next stage the findings from the focus group discussions will be validated and quantified in a large-scale Delphi survey.

As with any qualitative research methods, it is important to reflect upon any bias that may be present in the research findings. The invitee knew that the discussions were a part of the Green Logistics project. Hence, there is a risk that they may have wanted to

influence the research findings, for example in order to promote ideas that could be beneficial for their sectors. Inviting a large sample of representatives and emphasising the academic nature of the project at the beginning of each meeting may have minimised the risk of such behaviour.

Finally, it needs to be stressed that frequency of comments is not necessarily a good measure of a factor's impact. Some issues may be more familiar or common to the majority of participants or attract greater media coverage. However, it does not mean that their impact on the road freight transport sector will be very significant in the future. On the other hand, there may be factors not yet expected by the wider community of logistics specialists to have a great impact, and thus not commented on so frequently. That is why all issues, even those mentioned just once, are discussed in this Chapter. The relative strength and importance of each factor will be investigated in the next section of the thesis using data from the Delphi survey.

5.4. Conclusions

The future trends regarding supply chain structure, freight modal split, vehicle utilisation and fuel management will determine the environmental performance of road freight transport. This Chapter has presented the first stage of the empirical research which used focus group discussions to try to determine BAU trends in key freight, logistics and environmental variables. Also at a corporate level, awareness of likely changes in a company's environment can help to support its supply chain decisions and, in the longer term, to strengthen its competitive position. This is particularly relevant for this research project as it aims to take a business perspective in the forecasting process. Considering the issues discussed in this Chapter, it is important to differentiate between the factors that a company can influence and those imposed by the forces external to the corporation, e.g. government. In the case of the variables independent of the company (e.g. road pricing or fuel taxes), the main responsibility of a decision maker will be to ensure the best possible reaction to mitigate any adverse effects of these changes in the business environment. Understanding the factors that the company can control and the relationship between them puts a business into a position where optimum economic and environmental performance can be achieved. Greater awareness of the key factors influencing the transport intensity of supply chain operations, the extent of empty running of trucks, vehicle load factor and fuel efficiency can help to make logistical process more sustainable in economic, social and environmental terms.

One of the main conclusions from the focus group discussions is that the interaction between companies within a supply chain can significantly impair or improve the overall sustainability of this supply chain and, at the macro-level, impact on the performance of the road freight transport sector as a whole. The more powerful partners can force other companies in the supply chain to compromise the efficiency of their distribution in order to provide the required level of service. Conversely, by forming closer relationships corporations can develop a broader view and optimise the flow of goods across the chain, contributing to overall better performance in the freight transport sector.

The discussions also indicated that the logistics industry is keen to improve its environmental performance and a variety of initiatives are currently being undertaken. However, there is a range of potential measures that could lead to further improvements, which are not yet being implemented, largely due to limited knowledge and awareness among the transport representatives. Also the uncertainty about the full environmental consequences of such measures is delaying implementation. The use of alternative fuels is one example of an area where participants felt a lot could be done, but they were not sure which solutions would be most beneficial. More guidance, supported by scientific analysis and evidence, would be welcomed by the logistics sector. Freight Best Practice guides were mentioned as an example of such a useful initiative. It was also emphasised that green measures are more likely to be popular, if they bring economic benefits to the organisations. One delegate explained that from a business perspective, *“If being green does not mean making money, nobody is going to do it. There is a need for commercial solutions. Companies simply need to make money from their environmental initiatives”*. This indicates that environmental measures which are not likely to result in direct positive cash flows, may have to be enforced by national and/or international legislation or industry-specific regulations.

It also appeared from the discussions that supply chain structures within the UK have reached their maximum level of centralisation. The participants' views on the possible changes in average length of haul and handling factor suggest that, although there may be some shifts within sectors, the UK-wide situation is going to remain relatively stable. Furthermore, even though the idea of using alternative modes for moving freight stimulated a lively discussion, a more positive attitude towards waterborne transport

than towards rail was apparent. It was even said directly that “*Nobody has a problem with a concept of moving more freight to rail. It is the reality that prevents this from happening at the moment*”. However, even waterborne transport did not seem to be considered as a viable logistics option for the majority of organisations represented. It also seemed that companies are quite successful in optimising utilisation of their fleets. Also, they tend to see further reductions in empty running and improved loading of HGVs as more realistic and feasible ways to minimise the CO₂ emissions from their operations than for example modal shift. This suggests that the focus of future policies should be on providing companies with support and solutions to maximise efficiency of their road freight operations, rather than on forcing more shipments onto alternative modes, which may not yet be ready to efficiently handle a more diverse range of product flows.

Organisations invited to participate in this research represented a broad range of logistics activity, enhancing the credibility and wider applicability of results. The main objective of this focus group research was to confirm the validity of the issues identified in the literature review and to explore any new factors that had not been part of academic investigations. The findings presented in this Chapter have been used to develop a Delphi questionnaire survey that aimed to validate, generalise and quantify the trends identified by the focus group experts. The results of this survey are presented in the next Chapter.

Chapter 6. Quantification of Future Impacts- Delphi Survey

Aims of the chapter:

- *To outline the Delphi survey research process*
- *To present results of the Delphi survey*
- *To discuss the likely future environmental impact of road freight transport based on expert projections elicited from the questionnaire*

In the previous Chapter the findings from the focus group research were summarised. Based on them, a survey questionnaire was designed aiming to elicit expert opinion and produce a forecast of business-as-usual (BAU) trends in key logistics and supply chain variables and associated environmental effects of road freight transport up to 2020. It employed the Delphi method to survey the opinions of a large and varied sample of logistics and supply chain experts representing different types of organisations within supply chains and a wide range of industry sectors. The methodological assumptions underpinning the Delphi method were discussed in detail in Chapter 4. This Chapter outlines the research process, i.e. design and administration of both rounds of the questionnaire survey and analysis of the data collected. In the next section, the findings of the survey are presented and likely changes in the key logistics variables identified within the analytical framework introduced in Chapter 3 are discussed.

This part of the research project is both exploratory and explanatory in nature. The objectives are to elicit projections of future changes in major logistics parameters and to provide an explanation of why these changes are expected to occur. As referred to in the literature review part of this thesis, several studies of the future demand and associated environmental effects of transport have already been carried out and published. However, this research is unique in the sense that it focuses solely on a particular segment of the transport sector, namely road freight transport. It also results not only in a forecast of likely CO₂ emission levels from HGV activity in 2020 but provides an in-depth explanation and understanding of underlying causes.

6.1. Research Design and Analysis

The main Delphi survey was conducted between January and August 2008. Before that, the pilot study was carried out in December 2007. The invitations to take part in the survey were emailed to the potential participants on the 14th January 2008, followed by

a reminder on the 6th February 2008. The first round closed on the 7th March 2008. The initial data were then analysed and used to prepare the second round questionnaires. The invitations to take part in the second round were emailed to the first round participants on the 24th of June 2008, followed by a reminder email on the 30th July 2008. The survey closed on the 15th August 2008.

6.1.1. Questionnaire design and administration

After careful consideration, it was decided to use a web-based questionnaire to conduct the Delphi survey. It has been proven that in logistics, supply chain and operations research the use of a web-based questionnaire overcomes many of the disadvantages associated with traditional mail-based survey methods (Forza, 2002, Griffis et al., 2003). Griffis et al. (2003) show that use of email and the Internet in survey research can lead to higher response rates. According to them, electronic questionnaires also tend to be completed more quickly and data are received much sooner, “with 43% of the survey responses arriving within eight hours of the two electronic contacts” in the case of their particular research (p. 254). Further, the above authors also did not find any significant differences in the characteristics of the data collected electronically and by mail, which proves that both methods result in comparable quality of data. Also, with wide Internet and email access, electronic questionnaires are more economical, especially when the sample size is large.

Standard software to design and administer web-based questionnaires is now widely available online (e.g. www.surveymonkey.com or www.survey.bris.ac.uk). It was not possible to use this software for this Delphi survey, however. In anticipation of the need to customise a questionnaire for each respondent in the second round, an IT company was employed to design an electronic version of the questionnaire (www.procureweb.ac.uk).

The design stage of a questionnaire is crucial for the success of the research. In the literature there are numerous warnings and descriptions of poorly designed and administered questionnaires (for instance Sackman, 1974, Goldschmidt, 1975, Rowe et al., 1991, Janes, 1999). Typically, the formulation of questions poses a problem especially when they are too abstract and open to different interpretations (Sheatsley, 1983, Tapio, 2002a). “In formulating the questions the researchers should ensure that the language of the questionnaire is consistent with the respondent’s level of

understanding. If a question is not understood or interpreted differently by respondents, the researcher will get unreliable responses to the question, and these responses will be biased” (Forza, 2002, p. 168). Focus group discussions carried out at the earlier stage of this research project were of a great assistance here. Apart from producing results used to formulate relevant questions, they helped to ensure clear, unambiguous and precise use of technical terms and definitions. Also, while designing the questionnaire, definitions and measurement units were specified where appropriate.

A pilot questionnaire was designed to test if the questions are “good, nonbiased and answerable and will give good data and insight into the problem” (Janes, 1999, p. 322). The invitations were emailed to 10 industry experts of whom six agreed to help. The ‘pilot respondents’ were asked to fill in the questionnaire and provide feedback on its design, usability and questions asked, as recommended by Fink (1995). Received feedback was very positive, hence no further changes were made to the questionnaire and pilot responses were included in the overall survey results. At this stage, it was decided that the survey questionnaire was ready to be launched.

At the start of the questionnaire, some general information about the survey was given. It included the purpose of the study, basic information on the researcher and Heriot-Watt University, appropriate instruction on how to fill in the questionnaire and how long this was going to take. The questionnaire was structured on the basis of the theoretical framework introduced in Chapter 3. The respondents were asked what changes would occur by 2020 using the following three types of questions:

- To what extent would a particular variable increase or decrease against a base index value of 100, representing the current level?
- To what extent would a particular variable change as compared to its actual value in 2006?
- What would be the intensity, importance or impact of future changes in a particular variable rated on a five point Likert scale?

In the second round, the participants were sent the questionnaire again but this time annotated with a mean panel responses from the first round and their previous responses. A generic first round questionnaire and a sample customised second round questionnaire are shown in Appendices A and B.

A primary objective of this thesis is to measure and quantify future environmental impact of road freight transport. This is achieved by obtaining measurements of expected / perceived changes in the identified key logistics variables and aggregating them. Hence, the concept of measurement scales is particularly relevant to this research. A measurement scale can be defined as a set of rules to assign numbers to objects or events in order to measure the quantities or intensity of their attributes or to classify them into a number of categories with respect to a given attribute (Anderson et al., 1983, Alreck and Settle, 1995, Sapsford, 1999).

Two types of scales were used:

- A simple ratio scale to measure absolute changes in the investigated parameters (Fowler, 2002).
- An interval five point Likert scale to measure experts' opinions, expectations and perceived importance of a number of variables.

Likert scale is the most widely used rating scale to measure attitudes in survey research. It was developed by a psychologist Rensis Likert (1932) and named after him. When this scale is used, respondents are presented with a set of attitude statements, typically to be rated on a scale from one to five. As a result, numerical values can be used to summarise all the responses (Alreck and Settle, 1995). Likert scales are believed to produce good results in terms of validity and reliability of measurements (Anderson et al., 1983).

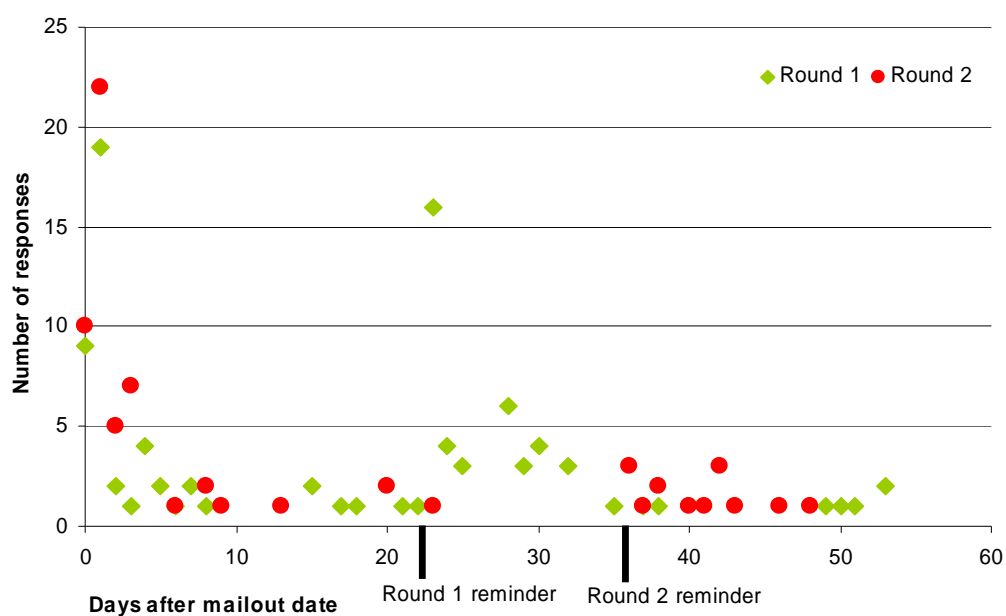


Figure 6.1. Response pattern

Figure 6.1 shows the spread of responses after the questionnaire was launched. 32% and 56% of the total responses were received within first three days from the mailout date in the first and second round, respectively. A further 24% and 9% of responses were received within three days from sending a reminder in both rounds, giving a total 56% and 65% of responses received within three days of any type of communication with potential participants. This increases to 85% and 92% if 10 day periods after sending an invitation or a reminder are considered.

6.1.2. Sample

The aim of the research was to elicit expert projections on the future course of key factors determining the environmental performance of road freight transport. Hence, the population in this research project refers to the group of people that can be considered as logistics and supply chain experts. A population frame of approximately 600 specialists was constructed on the basis of networking with professional and trade bodies, participation in workshops and conferences or being active in research within relevant subject areas. A purposive selection process allows the data to be collected purposefully, that is, in order to carry out systematic comparisons (Barbour, 2007). The aim was to include a broad cross-section of respondents. As the main objective of the Delphi study was to produce a reliable forecast based on expert judgement, only those specialists considered to have sufficient knowledge and experience of the subject were selected for inclusion in the population frame. From this population frame, a stratified random sample was drawn to reflect the shares of seven different types of organisation involved in logistics: manufacturers, retailers, logistics service providers, public policy-makers, trade organisations and enablers. This classification was introduced in Chapter 6, but at this stage one more category of participants was added. Researchers are the participants representing academia, i.e. logistics and supply chain-related research units and institutes. “Stratified random sampling is a very useful type of sampling since it provides more information for a given sample size. (...) This procedure ensures high homogeneity within each stratum and heterogeneity between strata. Stratified random sampling allows the comparison of population subgroups and allows control for factors like industry or size which very often affects results” (Forza, 2002, p. 165).

To determine the proportion of respondents in each stratum, the data on the number of companies by the current UK Standard Industrial Classification (SIC) codes was pulled from the FAME database. FAME is a database that contains information on 3.4 million

companies in the UK and Ireland. It is published by Bureau van Dijk, one of Europe's leading publishers of business information. Although an attempt was made to produce a stratified sample reassembling the proportions of different types of organisations in the general populations, the final composition of the sample is usually affected by response rates which may vary between respondent groups.

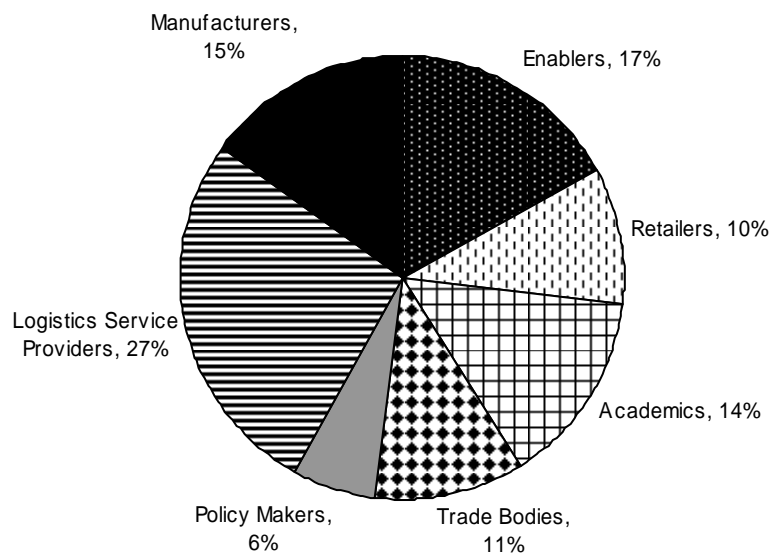


Figure 6.2. Sample composition by type of organisation (n = 100)

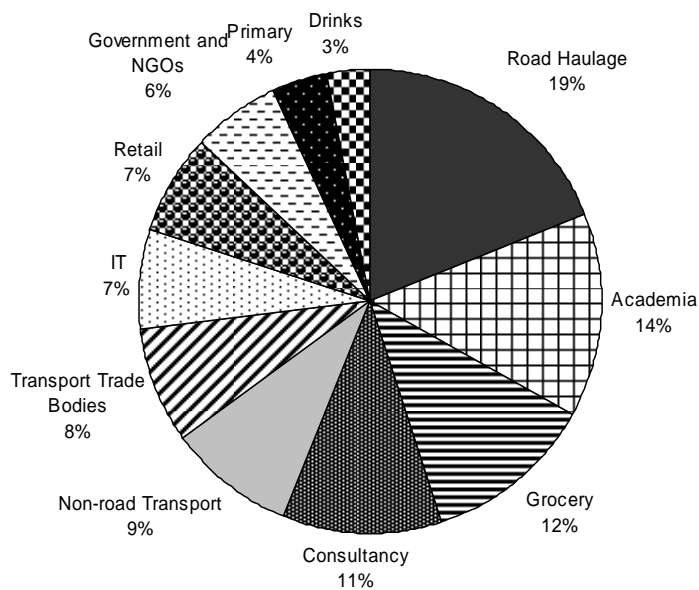


Figure 6.3. Sample composition by industry type (n = 100)

An invitation to join the Delphi panel was emailed to 347 potential participants. It was decided to send invitations to these participants instead of using an open web-survey. It has been shown that open web-questionnaires may produce inaccurate results as contributors self-selecting themselves to take part in the survey could be atypical of the target population thus biasing the findings (Grandcolas et al., 2003). In the first round 100 invitees filled in the questionnaire giving an overall response rate of 29%. Griffis et al. (2003) report that survey response rates for large samples in studies among populations of logistics managers published in the *Journal of Business Logistics* between 1997 and 2001, lay between 4.0% and 32.7%. Larson (2005) in his analysis of mail survey research reported in the *International Journal of Physical Distribution & Logistics Management* between 1989 and 2003 reports response rates ranging from 2.5% to 97.7%. However, in his review all sample frame sizes are included in the range, with the lowest being 30 questionnaires mailed out to the potential participants. Hence, the achieved response rate of 29% was judged to be satisfactory. Figures 6.2 and 6.3 show the composition of the sample by type of organisation and industry. It is worth noting that, as mentioned above, the sample has been stratified to reflect the shares of different types of supply chain members. This categorisation was prioritised and there was no attempt made to use industry sectors as a stratification criterion. Hence, the classification of participants by industry represented is of a secondary effect and was not influenced by the researcher.

In the second round, the participants were offered an option to modify their answers in the light of the first-round results. They were also informed that if they did not fill in the questionnaire again it would be assumed that they did not wish to alter their first round responses. 66 participants filled in the questionnaire again, 59 of whom changed at least one answer in almost all cases increasing the degree of consensus. The average standard deviation of the responses declined between the rounds by 9%. A similar degree of convergence was achieved in the EU-TRILOG Delphi survey (McKinnon and Forster, 2000).

The expertise was defined in terms of “sufficient knowledge and experience” and it was assumed that at least five years of experience in logistics-related job is required to fulfil the selection criteria. The vast majority of participants occupied senior positions within their organisations (83%). Age and gender of participants were not considered as selection criteria. Age is typically positively correlated with years of experience and the

later criterion was regarded as more important. 96% of those who responded to the survey were male. This is a higher proportion than the industry average where almost 80% of people holding logistics-related positions are male (Figure 6.4). The impact of gender on logistics performance is still being discussed (Tatham and Kovacs, 2008). There is some evidence that sex of a logistician may have an impact on performance in some areas, for instance in purchasing negotiations (Min et al., 1995). The particular characteristics of female logistics executives have also already been investigated (Cooper et al., 2007) but as yet there has been no attempt to compare them with those of male logistics professionals. Given the lack of evidence that gender is a significant differentiation factor in the logistics profession, the gender criterion was not considered to be relevant for this research.

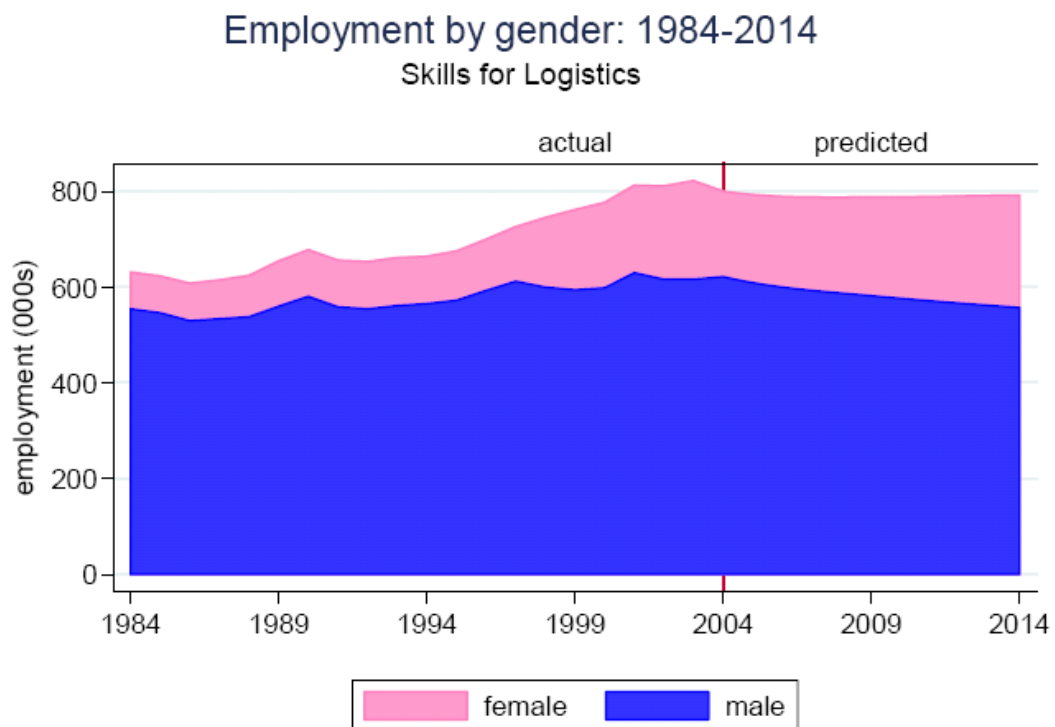


Figure 6.4. Employment in logistics-related jobs, by gender
Source: Dickerson et al. 2008

6.1.3. Testing for normality and homogeneity of variance

In order to select statistical tests to carry out analysis presented in the later sections, the data was first tested for normality using two methods: normal Q-Q probability plots and Shapiro-Wilk (W) test (sample results of these tests are shown in Figure 6.5 and Table 6.1). Normality is indicated on a Q-Q plot if response points are clustered around a straight line (Field, 2005). However, although the values should fall along the straight line, it may be difficult to assess if any observed deviation is large enough to be

important. Hence, the Shapiro-Wilk (W) test was applied as an additional check as it is considered a well-established and powerful test of the degree of departure from a normal distribution. It can be applied for any sample size greater than three and less or equal than 2000 (Royston, 1992, Forza, 2002).

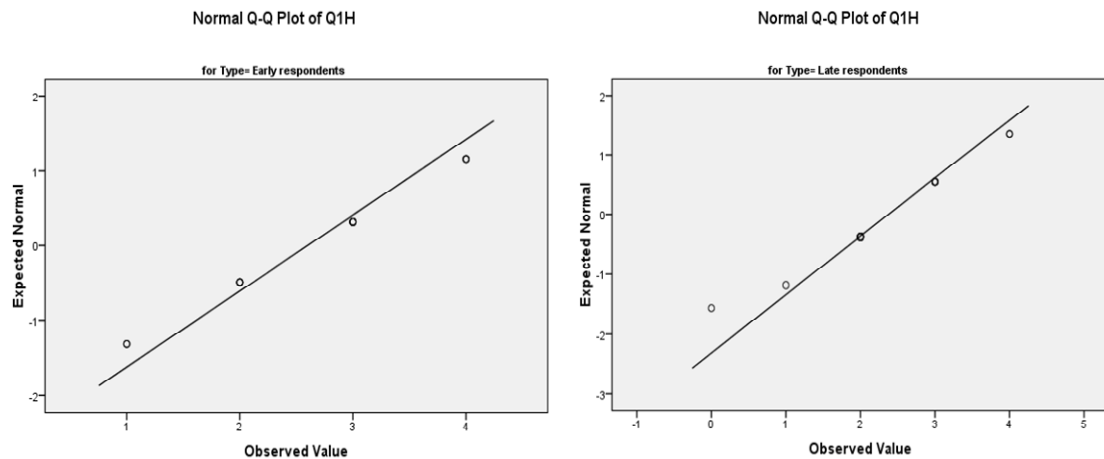


Figure 6.5. Sample Q-Q plots

Both methods of testing for normality were used as suggested by Shapiro and Wilk (1965): “The W test had its inception in the framework of probability plotting. The formal use of the test statistic as a methodological tool in evaluating the normality of a sample is visualised by the authors as a supplement to normal probability plotting and not as a substitute for it” (p.610). Further, the Shapiro-Wilk (W) test is considered to be more powerful and reliable than the Kolmogorov-Smirnov test for normality (Shapiro et al., 1968, D'Agostino and Stephens, 1986, Field, 2005).

Tests of Normality							
Type		Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Q1H	Early respondents	.195	15	.128	.896	15	.082
	Late respondents	.232	16	.021	.898	16	.075

a. Lilliefors Significance Correction

Table 6.1. Testing for normality-sample results

The Shapiro-Wilk (W) test tests the null hypothesis that a sample is taken from a normal distribution. The significance value (column Sig. in Table 6.1) represents the probability

of incorrectly rejecting the null hypothesis. Hence, if the test statistic is significant (usually when sig. < 0.05), then the hypothesis that the respective distribution is normal should be rejected. Further, the closer the test statistic is to one, the more normal the sample is.

Where the data was shown to be normally distributed a test for homogeneity of variance was carried out (Levene's test) to fulfil all assumptions underpinning for instance the t-test or ANOVA (Table 6.2). The Levene's test tests the null hypothesis that the two group variances on the dependent variable are equal. The null hypothesis should be rejected if the significance level is small (sig. < 0.05), i.e. test statistic is significant (Ho, 2006).

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Q1H	Equal variances assumed	.022	.882	.622	29	.539	.22500	.36156	-.51447	.96447
	Equal variances not assumed			.623	28.977	.538	.22500	.36109	-.51354	.96354

Table 6.2. Levene's test and t-test - sample results

6.1.4. Non-response bias

The data from both rounds was entered into a statistical software package (SPSS 16.0) for analysis. It was first tested for the non-response bias which may arise when the characteristics of the respondents vary significantly from those of the non-respondents. Most of the literature focuses on non-response to mail surveys. However, Hudson et al. (2004) could find no evidence that the incidence of non-response bias was significantly different in mail or Internet surveys. Non-response bias may occur even in research with relatively high response rates (Carter and Jennings, 2002). This is of a particular importance in the case of a Delphi study where there is a need not only to achieve a desirable response rate in the first round but also to maintain a high level of response in the following iterations (Hsu and Sandford, 2007b). Lambert and Harrington (1990) suggest that non-response bias can be a problem where response rates are lower than 40%. The most common protection against this bias is to increase response rates. This was done in the Delphi survey by sending out follow-up emails in each round. Additionally, in the second round a personalised questionnaire was prepared, summarising their responses in the previous round. This helped to stimulate their

interest in the study and maintain a high level of expert involvement. The panellists were also informed that they would be sent a report summarising the research findings once the study was completed.

Having collected the data, one way of testing for non-response bias is to compare the answers of early and late respondents to the survey (Diaz de Rada, 2005). Participants who respond in later waves of the survey (e.g. after a follow-up letter) may only have responded because of the additional stimulus and, thus, be similar to non-respondents (Armstrong and Overton, 1977). In this study the first and last quartile of respondents in both rounds were compared to assess the potential non-response bias. The data collected for all survey questions was first tested for normality and homogeneity of variance within the early and late respondent groups. A t-test or a Mann-Whitney (U) test was then used to compare the differences in responses, depending on whether the distribution has proven to be normal and of homogeneous variance or not.

The t-test is used for testing the differences between the means of two independent groups. The null hypothesis assumes no difference in means between the groups. It should be rejected if the magnitude of the test statistic (t) exceeds the critical t-value from the table of the t-distribution and has significant two-tailed probabilities (Morris, 2003). For 29 degrees of freedom (n_1+n_2-2 , i.e. $15+16-2$) and a significance level of 5%, the critical value t is 2.045, against which the calculated t-test statistics were compared in order to identify cases with different mean responses between early and late respondents (Table 6.2). There were no statistically significant differences found in any of the questions tested with the t-test.

Test Statistics ^b		Test Statistics ^b	
	Q4E		Q13E
Mann-Whitney U	105.000	Mann-Whitney U	65.000
Wilcoxon W	225.000	Wilcoxon W	201.000
Z	-.680	Z	-2.452
Asymp. Sig. (2-tailed)	.496	Asymp. Sig. (2-tailed)	.014
Exact Sig. [2*(1-tailed Sig.)]	.572 ^a	Exact Sig. [2*(1-tailed Sig.)]	.030 ^a

a. Not corrected for ties.
b. Grouping Variable: Type

Table 6.3. Mann-Whitney test sample results

The Mann-Whitney (U) test is used as an alternative to the t-test when the data within the groups are not normally distributed. It can detect differences in both shape and spread, i.e. for two independent samples, it tests whether one variable tends to have values higher than the other (Hart, 2001b). The null hypothesis assumes that the mean rankings of the two groups being compared are equal. It cannot be rejected if the absolute value of the test statistics (Z) is less than or equal to 1.96 i.e. the test is not significant (Exact Sig. ≥ 0.05) (Bryman and Cramer, 1990, Field, 2005, Ho, 2006). Table 6.3 shows sample results of the Mann-Whitney (U) test for two selected questions. The results on the left side suggest no significant difference between early and late respondents, whereas the results on the right show the opposite.

Overall results suggested that the responses of the last quartile participants did not display statistically significant differences from the responses of the first quartile participants in most cases. In the first round, differences occurred in three, while in the second round in five out of 115 questions (2.6% and 4.3% of questions, respectively). As the differences occurred in less than 5% of cases in both rounds, it was concluded that no significant non-response bias was present.

6.1.5. Data analysis

In the next stage of the analysis, the spread of data for each variable was assessed visually by constructing histograms to detect cases with obvious non-normal distributions (for instance a binominal spread of responses). No such cases were identified. A sample histogram is shown in Figure 6.6.

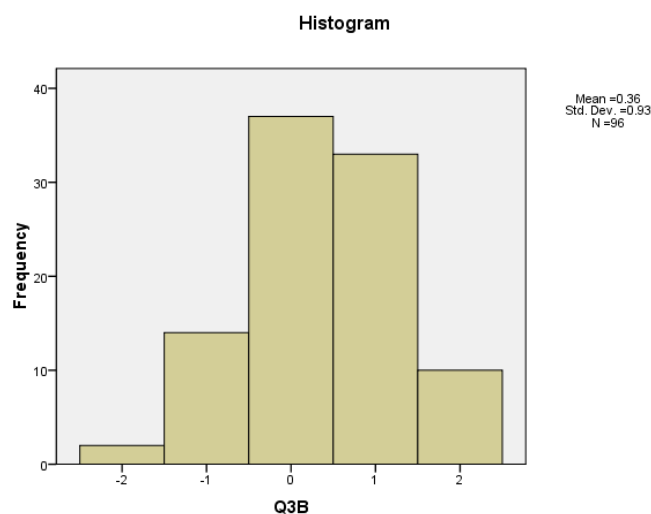


Figure 6.6. Sample histogram

The data was then tested for normality as described in the section 6.1.3. Statistical measures of central tendency and variability were calculated to summarise the experts' speculations. This analysis was conducted on the whole sample and then repeated for individual respondent groups. For the purpose of inter-group comparisons (by type of supply chain member and by industry sector) the data was tested for normality within groups and, where the data was shown to be normally distributed, a test for homogeneity of variance was carried out. In the case of questions where data within groups was normal and of homogeneous variance, a one-way analysis of variance (ANOVA) was carried out to detect whether there are significant differences in opinion between different participant groups. Where data were not normally distributed a non-parametric Kruskal-Wallis test was used instead of ANOVA.

A one-way analysis of variance (ANOVA) is used to compare means of three or more unrelated samples. It tests to what extent variance in the dependent variable is due to the independent variable (e.g. type of organisation represented) and to what extent it is due to other factors. The null hypothesis assumes that there are no differences in the sample means of the different levels of the independent variable. The test statistic F is derived by dividing the between-groups mean-square by the within-group one. If F is significant (i.e. Sig. < 0.05) there are statistically significant differences between groups (Bryman and Cramer, 1990, Wonnacott and Wonnacot, 1990) . Table 6.4. shows a sample output from ANOVA analysis in SPSS. In this example, the significance level is greater than 0.05 (Sig. = 0.122 >= 0.05), hence the test is non-significant and there are no significant differences in mean response to the questions between respondents representing different types of organisations.

ANOVA

Q14H					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10.465	6	1.744	1.735	.122
Within Groups	90.504	90	1.006		
Total	100.969	96			

Table 6.4. ANOVA – sample results

The Kruskal - Wallis test is a non-parametric test used to compare scores in more than two groups. It can be used as an alternative to ANOVA where the assumption of normal distribution within the sample cannot be met, and / or as an alternative to the Mann-

Whitney (U) test where more than two groups need to be compared. The null hypothesis tested by the Kruskal – Wallis is that the mean ranks of samples from the population are the same. If the test is not significant (Sig. ≥ 0.05), there is no difference in the mean scores between respondents of different groups (Bryman and Cramer, 1990, Ho, 2006). An output from SPSS for one of the questions is shown in Table 6.5. It shows the mean rank for each respondent group, the number of cases in each of them, the Kruskal - Wallis test statistic (chi-square) and its significance level. In the case of this sample question, Sig. = 0.38 ≥ 0.05 , hence the test is non-significant and there are no significant differences in the mean scores between different respondent groups.

Ranks				Test Statistics ^{a,b}	
TYPENUM		N	Mean Rank		Q16B
Q16B	Academics	14	50.50	Chi-Square	6.395
	Logistics service providers	25	46.18	df	6
	Enablers	16	46.72	Asymp. Sig.	.380
	Manufacturers	15	40.57		
	Policy makers	6	64.33		
	Retailers	9	60.33		
	Trade bodies	10	41.35		
	Total	95			
				a. Kruskal Wallis Test	
				b. Grouping Variable: TYPENUM	

Table 6.5. Kruskal – Wallis test – sample results

For the vast majority of the questions no statistically significant differences in opinion were found between the various respondent groups. Reference will be made later in this Chapter to variables on which statistically significant differences of opinion emerged.

Next, Pearson's correlation coefficient analysis was carried out in order to investigate whether there were any relationships between respondents' predictions of future changes in different variables. A Pearson's product moment correlation coefficient measures if and to what degree a linear relationship between variables exists. The value of Pearson correlation coefficient (usually denoted by r) always lies between -1 and 1. Thus, two variables can be positively or negatively related or there may be no linear association at all (Wonnacott and Wonnacot, 1990, Sapsford, 1999). "A coefficient of +1 indicates that the two variables are perfectly positively correlated, so as one variable increases the other increases by a proportionate amount. Conversely, a coefficient of -1 indicates a perfect negative relationship: if one variable increases the other decreases by a proportionate amount. A coefficient of 0 indicates no linear relationship at all and so if

one variable changes the other stays the same” (Field, 2005, p. 111). In the literature, there is a lack of clear consensus over guidelines to interpret the strength of correlation (Bryman and Cramer, 1990). Cohen and Holliday (1982) suggest the following levels of correlation strength: absolute value of r below 0.19 is very low, 0.2 to 0.39 is low, 0.4 to 0.69 is modest, 0.7 to 0.89 is high and 0.9 to 1 is very high. Field (2005) lists three sizes of correlation coefficient effect, i.e. ‘values of ± 0.1 represent a small effect, ± 0.3 is a medium effect and ± 0.5 is a large effect’ (p.111). Table 6.6. shows sample output from SPSS. It needs to be emphasised here that a significant relationship between variables indicates merely that the variables co-vary (i.e. changes in one variable correspond to changes in the other variable) and in no way implies causality (i.e. that changes in one variable are due to changes in the other variable) (Ho, 2006).

		Correlations			
		Q9A	Q9B	Q9C	Q9D
Q9A	Pearson Correlation	1.000	.039	-.122	.159
	Sig. (2-tailed)		.718	.254	.133
	N	90	90	89	90
Q9B	Pearson Correlation	.039	1.000	-.232*	.089
	Sig. (2-tailed)	.718		.029	.406
	N	90	90	89	90
Q9C	Pearson Correlation	-.122	-.232*	1.000	-.399**
	Sig. (2-tailed)	.254	.029		.000
	N	89	89	91	91
Q9D	Pearson Correlation	.159	.089	-.399**	1.000
	Sig. (2-tailed)	.133	.406	.000	
	N	90	90	91	93

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 6.6. Pearson correlation coefficients – sample results

Pearson’s correlation coefficient analysis was used to test how respondents’ perceptions of future factors influencing the environmental impact of road freight transport relate to each other and which relationships are the strongest. All possible combinations of questions were tested for potential correlations between them. This analysis aimed also to test validity of the overall survey findings by assessing the internal logic of responses. This was achieved by checking if there are significant correlations between variables that one would expect to co-vary. Thus, the Pearson correlation coefficient

was considered to be a useful technique to test the consistency of respondents' predictions.

The mean responses from the first and the second rounds were also compared to see if there were any significant changes in experts' attitudes between rounds. The analysis of what happens between rounds is an important part of the process as it shows not only whether a consensus has been reached and what the final opinion was, but also the extent to which the opinion of the panel as a whole changed between rounds (Greator and Dexter, 2000). For instance, changes in circumstances between rounds may result in altering experts' opinions. The survey was carried out between January and August 2008, a period during which some important changes occurred in the external business environment. Particularly notable were a 14% increase in the average price of diesel fuel (European Commission, 2008a) and negative press coverage about the use of biofuel. Only very minor changes in the average opinion were detected, however, suggesting that short-term market distortions did not influence the long-term outlook of the logistics and supply chain professionals consulted.

The final analysis is based on the results of the two-round Delphi study. The mean and standard deviation values were used to project the future trends. The mean values indicate the group opinion on both the direction of trends and their relative strength. Standard deviation measures how widely spread the values in the data set are, representing the range opinion within the panel.

As was noted before, the results summarised in the next part of the Chapter are based on the combination of the second-round responses, where participants revised their opinions (59% of the panel) and first-round responses for the remaining 41% of experts.

6.2. Survey Results

The survey consisted of 21 questions, many of them multi-faceted, resulting in a total of 119 variables. The experts were asked to express their views on a number of factors that may influence supply chain structures, modal split, vehicle management and fuel management up to 2020 and evaluate their likely impact. It needs to be noted here that, all 'current' values presented to the panellist in the questionnaire were based on 2005 or 2006 data, depending on the most recent set available at the survey design stage. However, as the survey started in 2007 and continued in 2008, it is assumed that when

experts compare future against ‘current’ values they refer to 2007 as a base year. As the changes in the key logistics parameter between 2005 and 2007 were marginal (as shown in Chapter 3) the potential inaccuracy resulting from changing the base year is negligible. The results of the survey are presented below. Detailed tables with mean values and standard deviations from both rounds are presented in Appendix C.

6.2.1. Importance of environmental concerns in logistical decision making

In order to investigate the impact of global warming on supply chain practice, participants were asked to assess to what extent concern about climate change had forced their companies to modify their freight transport operations over the last three years and how they expected it to affect their logistics systems in the future. The answers for the 65% of respondents belonging to companies with a freight transport operation were rated on a five-point Likert scale where 0 = not at all, 4 = large extent (Figure 6.7).

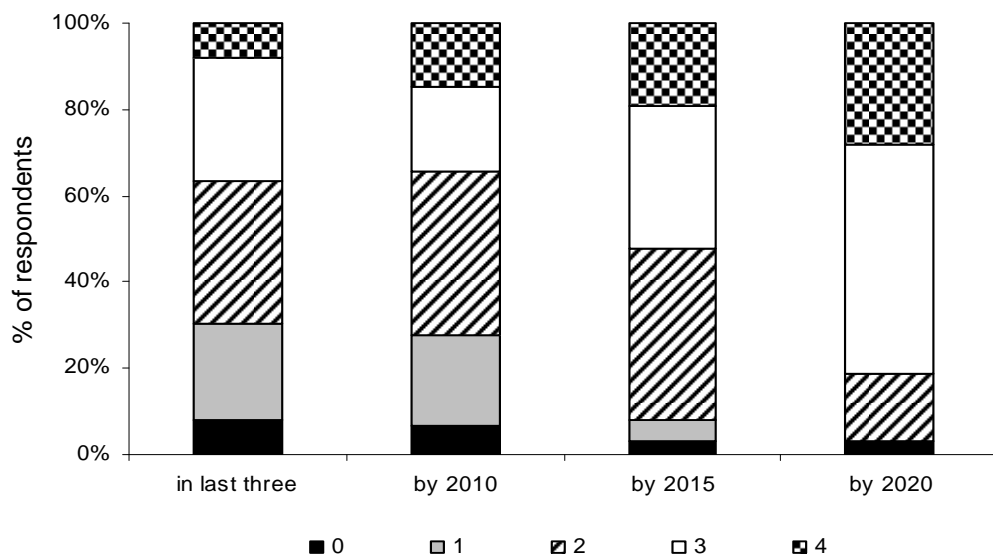


Figure 6.7. Impact of climate change concerns on companies’ freight transport operations

In the last three years, concern about global warming had exerted a significant influence on freight transport operations in less than 40 percent of the businesses (response 3 or 4). This percentage is expected to increase to over 80 percent by 2020. The proportion of company transport operations on which it will have no or a very limited impact (response 0 or 1) is likely to drop from 30 percent in last three years to 3 percent in 2020. This confirms that managers are aware of the growing scale and severity of the climate change problem. It also highlights the need for companies to understand how to measure and manage CO₂ emissions from their road fleets.

These findings are consistent with results of a worldwide survey of 536 transport and logistics professionals conducted by Eye For Transport (2007). 59% of respondents to that survey in the US, 57% in Middle East and Asia and 67% in Europe reported that green issues are either important or very important to their companies' strategy. The vast majority of respondents (69% in the US, 66% in Middle East and Asia, and 81% in Europe) expected that over the next three years environmental concerns will become more important to their transport and logistics processes. A Delphi study carried out by Deutsche Post DHL (2009) confirms experts' predictions that in 2020 climate change will be "the most important challenge facing humanity" (p.22) and that "climate change and its consequences will have a far-reaching effect on logistics. As one of the largest producers of CO₂ emissions, the logistics industry will find itself in a particularly difficult position – and under close scrutiny. The rising price of oil and the demand by customers for 'green' supply chains will require enormous investments and technological innovations" (p.52). Thus, freight transport operations will need to be fundamentally redesigned and "the logistics company that offers the most intelligent low-CO₂ solutions will emerge as the market leader" (p.53). Another recent survey of 125 supply chain professionals reported by Global Renewable Energy and Environmental Network (GREEN) (2009) identified "pressure to be more environmentally responsible and sustainable" as the main factor / force likely to change the way supply chains are managed in 2009 and beyond (p.18). Hence, the UK-based results reported in this thesis are fully consistent with findings of other surveys investigating the importance of environmental issues in logistics and freight transport operations now and in the future.

6.2.2. Future trends in key logistics variables

As discussed in Chapter 3, underpinning the future trend in these CO₂ emissions will be the relationship between the volume of road freight movement and economic growth. The Delphi panellists were asked to rate how road tonne-kms will grow relative to GDP up to 2020, where -2 = much slower, 0 = same rate, 2 = much faster. The mean response was -0.5 with a standard deviation of 0.9. This indicated that freight transport activity will continue to grow at a slightly slower pace than economic activity. The evidence that the decoupling trend observed in the UK between 1997 and 2004 is now becoming less pronounced was recently examined by McKinnon et al. (2008b). If the decoupling trend progresses at a pace predicted by the Delphi experts, it may not be strong enough to achieve major reductions in the environmental impact of freight transport. Thus, new

measures may be needed to decouple externalities from tonne-kms growth. This also suggests that micro-level efficiency improvements at a company or supply-chain level are necessary to achieve the overall increase in sustainability of the road freight sector.

Next, experts were asked to indicate if total freight tonne-kms are going to increase or decrease by 2020 against a base index value of 100, representing the current situation. The average response was 127 with a standard deviation of 21. This suggests that total tonne-kms will rise from 255 billion in 2007 to 325 billion tonne-kms in 2020.

How are the following road freight parameters likely to change between now and 2020?	Current	2020 (Mean)	Standard deviation
Average length of haul (km)	87	86	15.0
Handling factor (road freight transport)	3.4	3.4	0.7
Lading factor (%)	57	64	5.8
Empty running (%)	27	22	4.3

Table 6.7. Projected changes in supply chain structure and vehicle utilisation

As discussed in Chapter 3, supply chain structure and vehicle utilisation strongly influence the environmental performance of road freight transport sector. Supply chain structure is determined by the number of links and their average length. The number of links in the supply chain is measured crudely by handling factor which is a ratio of the tonnes-lifted to the actual weight of goods produced or consumed. Vehicle utilisation is measured by the lading factor and percentage of empty running. The lading factor is a ratio of the tonne-kms that a vehicle actually carries to the tonne-kms it could have carried if it was running at its maximum gross weight. Empty running is expressed as a percentage of the total lorry kilometres run. Table 6.7. presents the experts' opinion on future directions in these parameters up to 2020.

The panellists did not expect any significant changes in supply chain structure. The number of links is going to remain the same and their average length will be reduced by only 1 km to 86 kms. This suggests that that supply chain links are now almost fully extended and that, within a BAU scenario, the domestic pattern of road freight movement is going to experience only modest change by 2020. There will, however, be considerable improvements in the utilisation of HGVs by this date. Lading factor is expected to increase to 64 percent from 57 percent and only 22 percent of vehicle

kilometres will be run empty, down from 27 percent in 2006. If these improvements can be achieved, they will yield substantial environmental benefit.

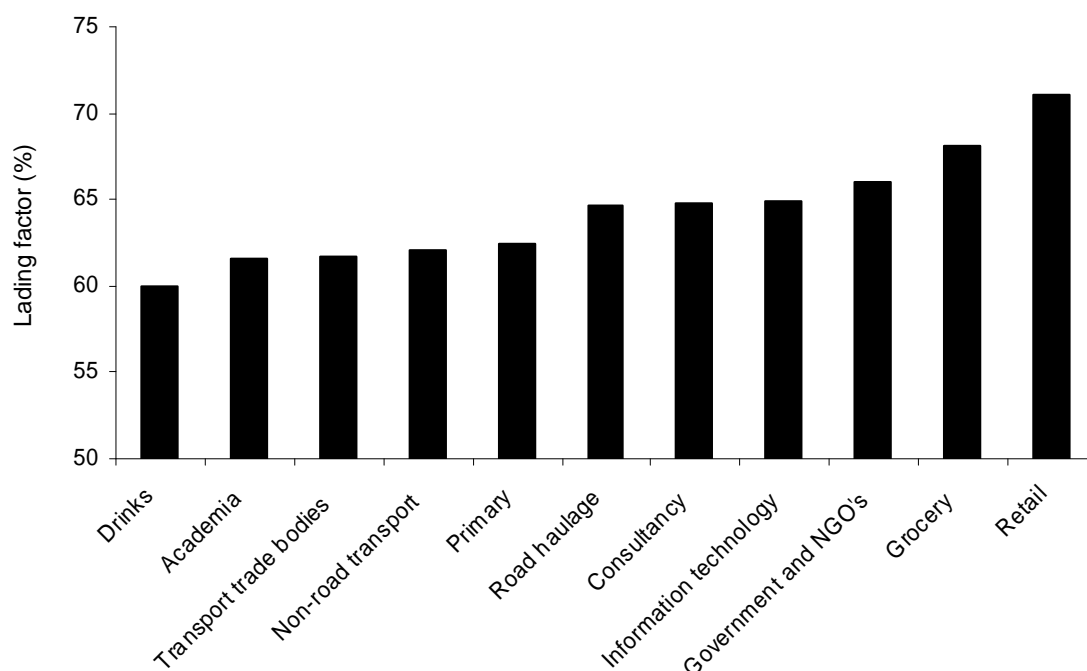


Figure 6.8. Differences in opinion on lading factor in 2020 (by industry)

It should be noted here that even though representatives of all industry sectors expected better vehicle utilisation in 2020, statistically significant differences in opinion emerged on the extent of the likely increase in lading factor and reduction in the percentage of kilometres run empty (Figures 6.8 and 6.9). Panellists from the retail sector were the most optimistic in their projections (average lading factor of 71% and drop in empty running to 19%). On the contrary, only a modest positive change was expected by the experts from the drinks industry (3% increase in lading factor and 2% reduction in empty running). A significant decrease in empty running was also anticipated by panellists involved in consultancy work (20%). However, their projections for the lading factor in 2020 were in line with the overall average (65%).

These changes will be a result of a number of factors occurring at company, supply chain and industry levels as well as in the wider socio-economic environment. The next section explains how logistical decisions made at different levels within a business affect key variables such as supply chain structure, modal split, vehicle utilisation and fuel management.

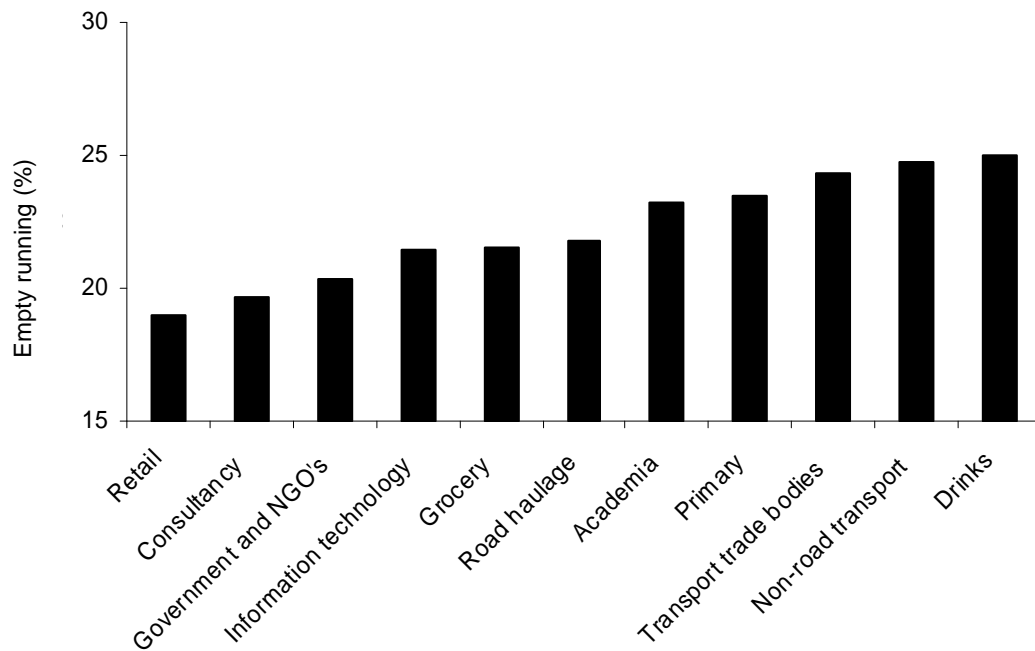


Figure 6.9. Differences in opinion on empty running in 2020 (by industry)

6.2.3. Factors influencing the environmental impact of road freight transport in 2020

CO₂ emissions from road freight transport are a function of the amount and type of fuel used. The amount of fuel used is closely correlated with a company's demand for road freight transport. In turn, the demand for road freight transport is the result of a series of decisions made at different levels within the corporate hierarchy. As explored in Chapter 3, for the purpose of this research factors affecting logistical decision making were divided into six categories, i.e.: structural, commercial, operational, functional, product-related and external.

The six sets of factors have a complex inter-relationship with the key freight transport variables as shown in Figure 6.10. Based on the focus group findings, the Delphi questions were defined to elicit the opinions of the logistics specialists on the impact of this wide range of factors. There was one issue, however, about which there was a great deal of uncertainty. This was the likelihood of a major switch to alternative fuels, and particularly biodiesel. Around the time of the Delphi survey, doubts were being expressed in official reports and in the press about the net environmental benefits of biodiesel (Searchinger et al., 2008, The Gallagher Commission, 2008). Given this uncertainty, it was decided to focus on the overall demand for fuel and potential for improving fuel efficiency, and not speculate about future solutions to change its average carbon content.

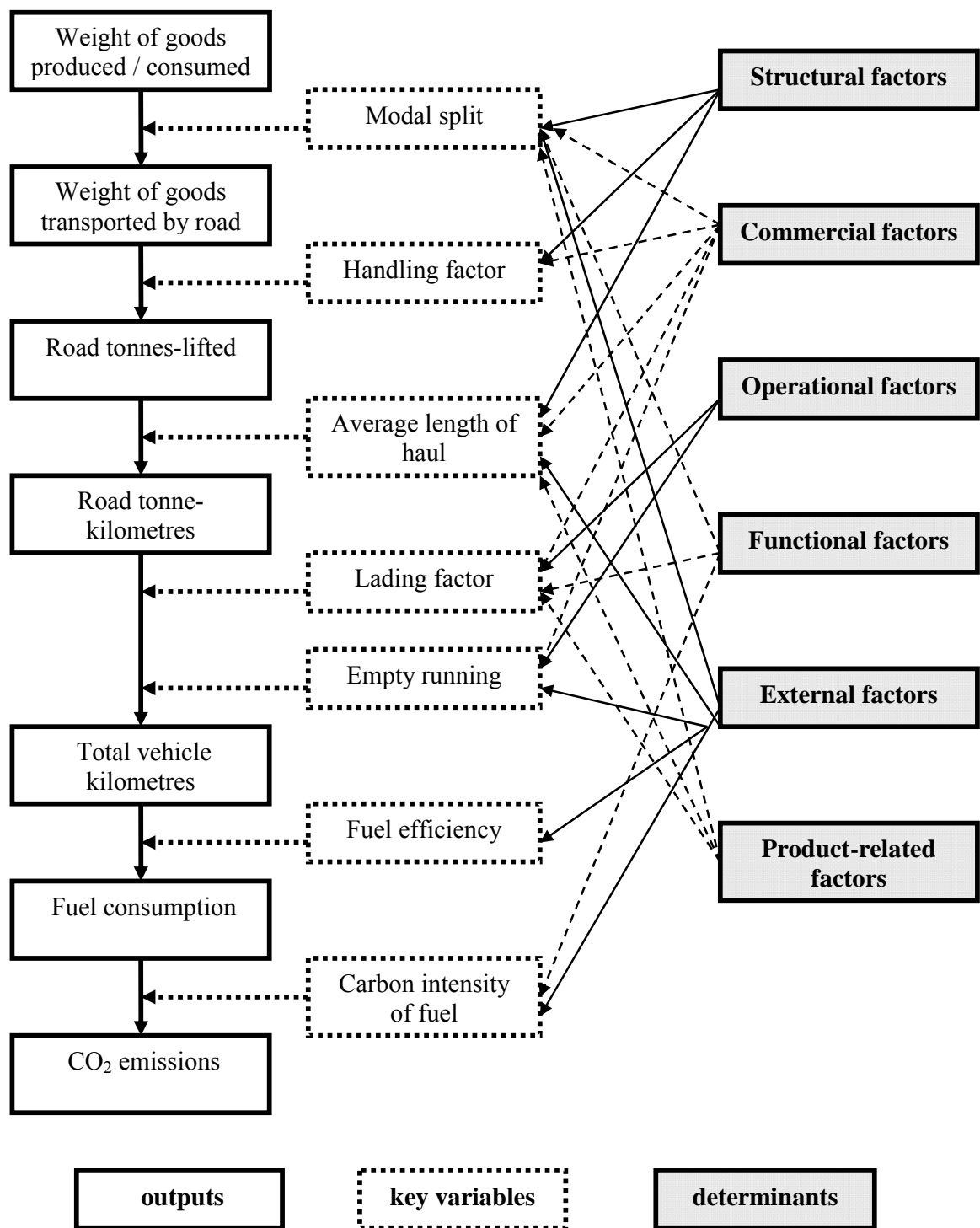


Figure 6.10. Relationship between logistical variables, determinants and CO₂ emissions

Structural factors

Structural factors determine the number, location and capacity of factories, warehouses and other facilities in the logistics system. As such, they exert direct influence on the

number of links in the supply chain and the average distance between them. In doing so, structural factors also indirectly affect the scope for transport mode selection. Structural decisions are usually made at top levels of the organisational hierarchy and those directly responsible for managing transport and logistics operation day-to-day have limited opportunity to influence them. Furthermore, it is often the case that structural decisions are imposed on a company by another partner in the supply chain (for instance a manufacturer may encourage their supplier to locate factories / distribution facilities within certain distance from the production plant).

There was general agreement that in 2020 the UK market will be predominantly supplied with goods produced overseas, channelled through hub ports and airports and then distributed through centralised logistics networks within the country. The majority of respondents believed that pressures to centralise production and inventory within the UK will remain much stronger than any tendency to decentralise (Figure 6.11).

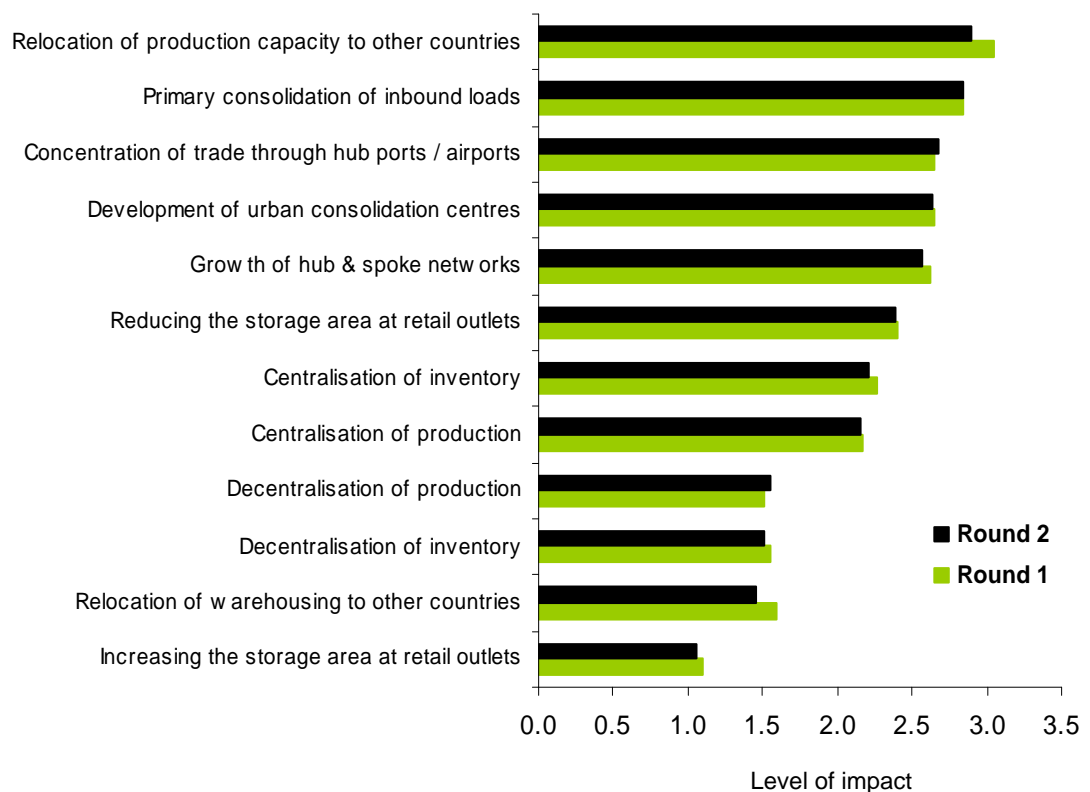


Figure 6.11. Structural factors affecting road freight demand (where 0 = no occurrence and 4 = occurrence to large extent)

However, in case of the centralisation of inventory, statistically significant differences in opinion emerged both between different types of specialist and between different sectors (Figure 6.12). For example, retail logistics managers predicted strong pressure

for further centralisation (mean response of 3.4), while academics and trade body representatives anticipated only a very limited increase (mean response of 1.5).

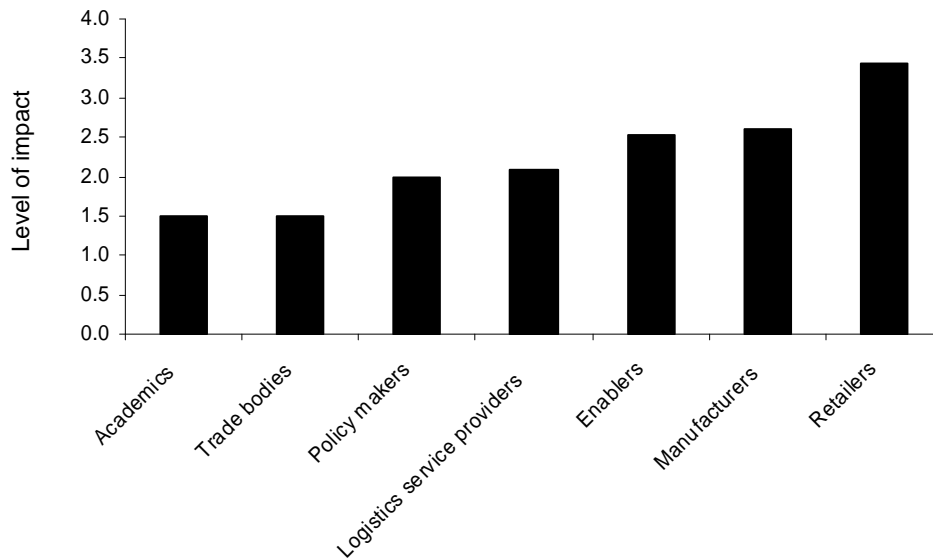


Figure 6.12. Differences in opinion on the extent of further centralisation of inventory (where 0 = no occurrence and 4 = occurrence to large extent)

There was also disagreement on the extent to which warehousing operations would relocate to other countries (Figure 6.13). Logistics service providers, policy makers and manufacturers expected a significantly greater degree of relocation (1.8, 1.7 and 1.7), than retailers, academics and trade bodies (0.8, 1.1 and 1.1).

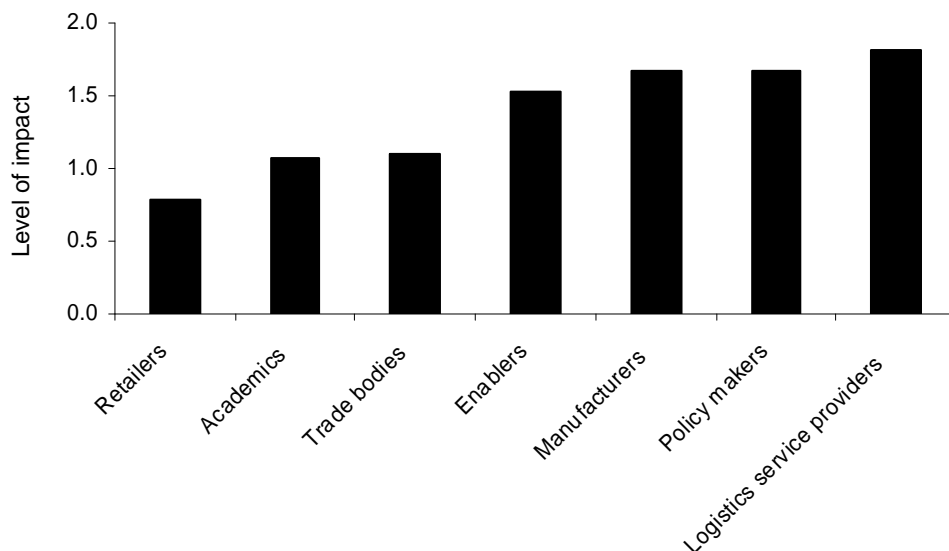


Figure 6.13. Differences in opinion on the extent of relocation of warehousing to other countries (where 0 = no occurrence and 4 = occurrence to large extent)

If, as the majority of respondents suggested, the geographical concentration of manufacturing capacity and inventory continues, average length of haul and total tonne-

kms are likely to rise. It was also anticipated that an increasing proportion of freight will be channelled through the hub-and-spoke networks of parcel and pallet-load networks and through primary consolidation centres upstream of retailers' distribution centres. This typically has the effect of adding links to the supply chain and therefore generating additional tonne-kms. The forecast growth of port- and airport-centric logistics, on the other hand, has the potential to streamline distribution channels, removing links and moderating any increase in tonne-kms. The investigation into the changing role of ports in supply chains was recently undertaken by Mangan et al. (2008). Their review suggests that although some ports provide a range of services to support the wider supply chain, there is still a significant potential for more ports to engage in more value adding logistics activities. The authors conclude that "ports need to move from taking a passive role in the supply chain to a more role, and port-centric logistics may be the vehicle to allow them to do this" (p.39).

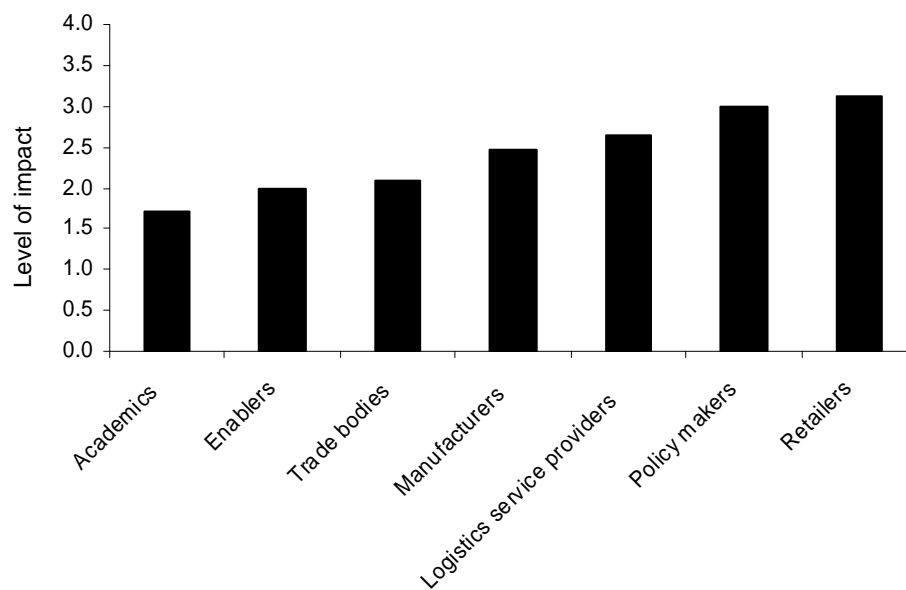


Figure 6.14. Differences in opinion on the extent of reduction of shop storage areas (where 0 = no occurrence and 4 = occurrence to large extent)

Increases in tonne-kms will not necessarily translate into a growth in vehicle traffic as vehicle loading may change. Structural factors can also indirectly influence vehicle utilisation. The centralisation of economic activity, the shift to hub-and-spoke networks and insertion of primary consolidation centres into distribution channels typically lead to greater consolidation of loads. In theory this should ensure that freight vehicle-kms increase less than tonne-kms. Other structural developments could have the opposite effect on vehicle utilisation. For example, it is predicted that in the retail sector, the

storage area in the shops is going to be reduced, forcing more frequent but smaller deliveries and potentially increasing the negative environmental impact of the store deliveries. Retailers, policy makers and logistics service providers expected greatest contraction of shop storage areas (scores of respectively, 3.1, 3.0 and 2.7) (Figure 6.14).

One of the panellists emphasised also that changes in the factors discussed above, particularly in regards to the centralisation / decentralisation pressures, will be very sector specific and may also vary significantly between regions.

Commercial factors

Commercial factors relate to companies' sourcing and distribution strategies and policies. These decisions also tend to be made at a high level of corporate decision making and are likely to impact transport mode choice, handling factor, average length of haul and vehicle utilisation.

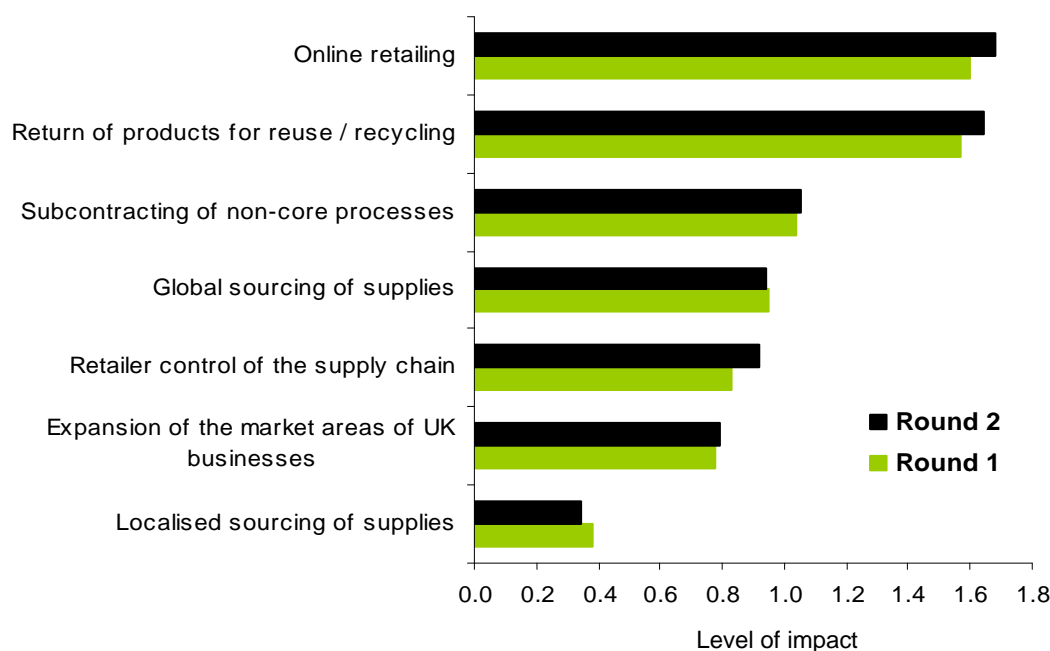


Figure 6.15. Commercial factors affecting road freight demand (where -2 = much less important than now and 2 = much more important than now)

Increases in the volumes of goods and services traded online and in the amount of product being returned for recycling or reuse were identified as two of the main commercial factors impacting on freight transport demand in 2020. Although previous focus group research suggested that there would be a significant increase in local sourcing, particularly in case of food produce, the Delphi panellists on average felt that this will occur only to a limited extent (Figure 6.15).

There was, nevertheless, a divergence of opinion between retailers and logistics service providers who felt that local sourcing in 2020 will be less important than now (-0.3 and -0.2), whereas trade bodies, academics and policy makers expected it to be more common (0.9, 0.8 and 0.7) (Figure 6.16).

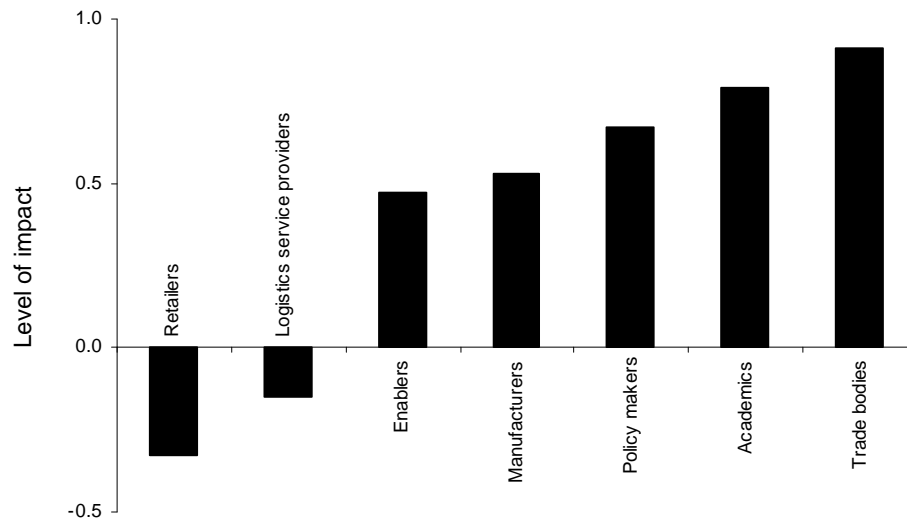


Figure 6.16. Differences in opinion on the importance of local sourcing in 2020 (where -2 = much less important than now and 2 = much more important than now)

On the other hand, there was nearly unanimous agreement that global sourcing will expand, though opinions differed on the extent of the trend, with retailers (1.6) and logistics service providers (1.2) assigning it higher scores than academics (0.6) and manufacturers (0.7) (Figure 6.17). The increase in global sourcing will increase freight volumes on external links though may have the effect of reducing the freight transport intensity of the UK economy. This may make it easier to cut CO₂ emission from domestic freight movement in the UK, but at the expense of a net increase in freight-related CO₂ emissions at a global scale (McKinnon, 2008). On balance, wider sourcing of products is going to remain more likely than any local purchasing strategies.

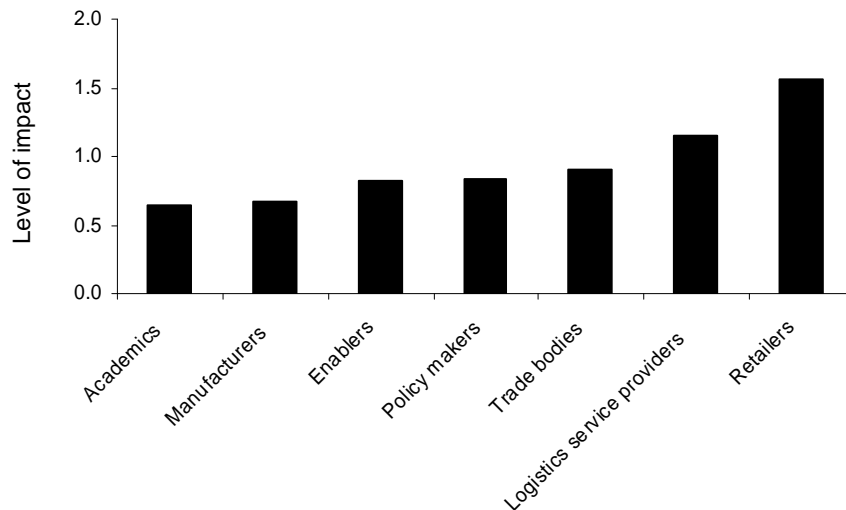


Figure 6.17. Differences in opinion on the importance of global sourcing in 2020 (where -2 = much less important than now and 2 = much more important than now)

According to the survey respondents, retailers' control over supply chains is going to strengthen even further, increasing their responsibility for improving the environmental performance across the chains. The largest growth in retailers' power was expected, perhaps unsurprisingly, by the retailers themselves (1.4), with logistics service providers (1.1) and trade bodies (1.1) averaging slightly lower scores (Figure 6.18). Academics, enablers, manufacturers and policy makers predicted smaller increases in retailers' domination over the channel. There was a general expectation that growing demand for "green" products and services may give retailers an incentive to involve supply chain partners in joint efficiency initiatives yielding an overall economic and environmental benefit.

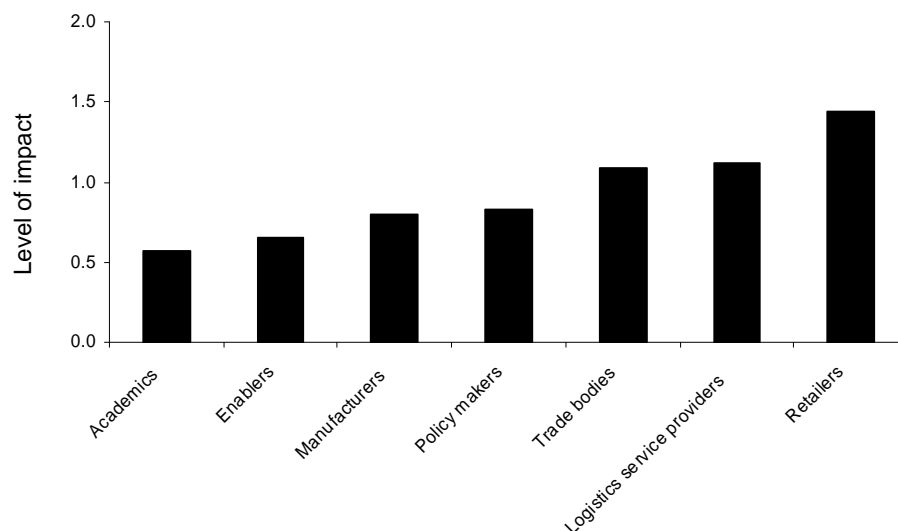


Figure 6.18. Differences in opinion on the importance of retailers' control over the supply chain (where -2 = much less important than now and 2 = much more important than now)

Panellists also anticipated a significant further increase in the ‘vertical disintegration’ of manufacturing operations with more non-core processes being subcontracted and, presumably, extra links being added to supply chains. The long term trend towards greater outsourcing of logistics is also expected to continue, with logistics service providers (1.4), enablers (1.3) and manufacturers (1.2) anticipating the strongest move in this direction (Figure 6.19). Similar expectations were expressed in recent survey of 120 logistics professionals conducted by Eye For Transport (2009) with 51% predicting that the increase in the use of logistics service providers is very likely and further 46% saying that this is likely to occur.

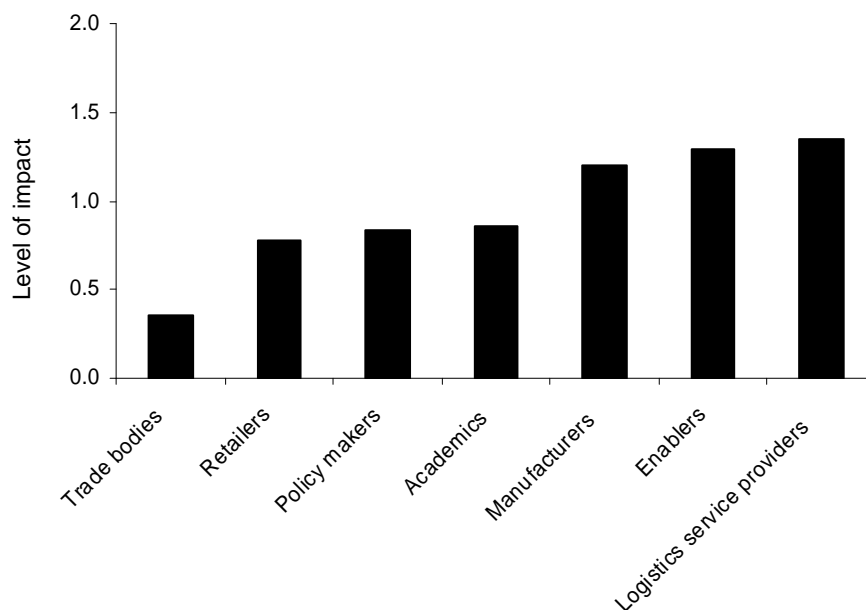


Figure 6.19. Differences in opinion on the importance of outsourcing in 2020 (where -2 = much less important than now and 2 = much more important than now)

Operational factors

Decisions regarding the operational factors affect the scheduling of product flow. They are typically made at mid-managerial level in a company organisational structure. Operational factors exert primary influence on empty running and lading factor.

Panel members forecast a further reduction of order lead times, modest tightening of the delivery windows, the need for slightly more frequent deliveries to retail outlets and even greater application of the JIT principle. In 2020, variability of order sizes will make it more difficult for companies to match load and vehicle capacity efficiently. These trends are likely to frustrate companies’ efforts to improve current levels of vehicle utilisation. Overall the Delphi panel did not endorse recent suggestions that

environmental pressures to use transport capacity more efficiently will force a relaxation of JIT regimes. On the other hand, it was predicted that an increasing proportion of freight would be moved during the night, when deliveries would be made on less congested infrastructure and freight vehicles able to achieve more fuel efficient speeds (Figure 6.20).

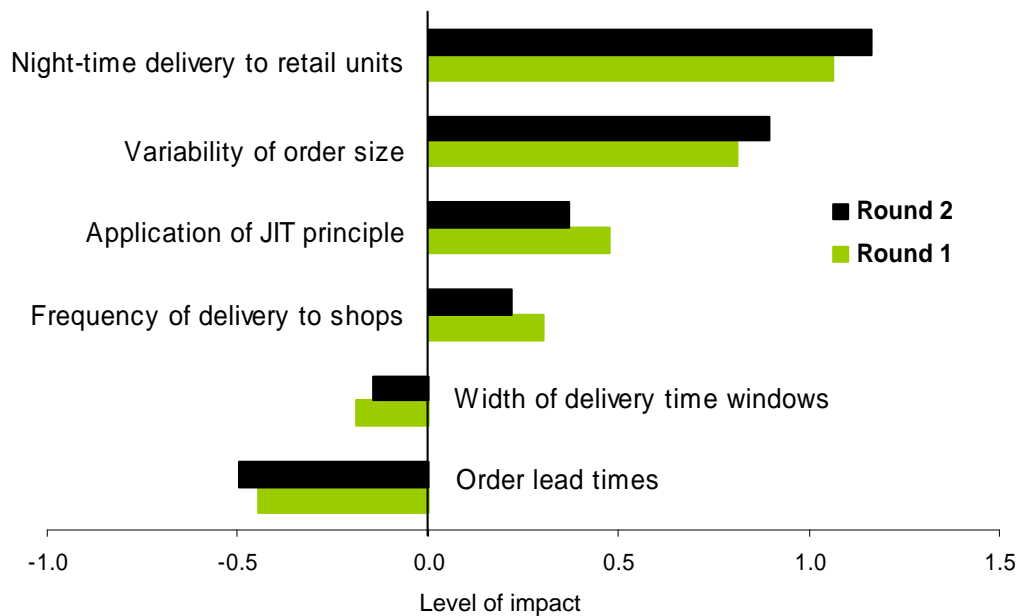


Figure 6.20. Operational factors affecting road freight demand (where -2 = large reduction and 2 = large increase)

One of the panellists added that the increase in incidence of ambient and temperature-controlled goods being carried on the same vehicle was a likely future change in logistics practices.

Functional factors

Functional factors relate to the direct management of transport resources. They usually relate to the choice of a vehicle, planning of loads and routeing of deliveries. Functional factors influence utilisation of vehicles, transport mode selection¹³, fuel efficiency and carbon intensity of fuel.

Within a logistics system defined by higher-level decisions made at the strategic, commercial and operational levels, managers still have considerable scope to ‘green’ the transport operation at a functional level. The panel predicted that by 2020 this will be facilitated by wide application of telematics and CVRS systems (Figure 6.21).

Companies are also expected to get more heavily involved in various collaboration initiatives, to improve the utilisation of their fleets by increasing the level of backloading and to achieve greater integration of production and distribution operations. Better matching of vehicle capacity to transport demands will lead to better resource planning and vehicle utilisation. Investment in double-deck / high cube vehicles is expected to rise, with the greatest uptake in the retail, road haulage and grocery sectors (2.0, 1.5 and 1.5) (Figure 6.22). Service quality requirements are going to remain important but increases in the real cost of transport may cause some rebalancing of cost and service priorities.

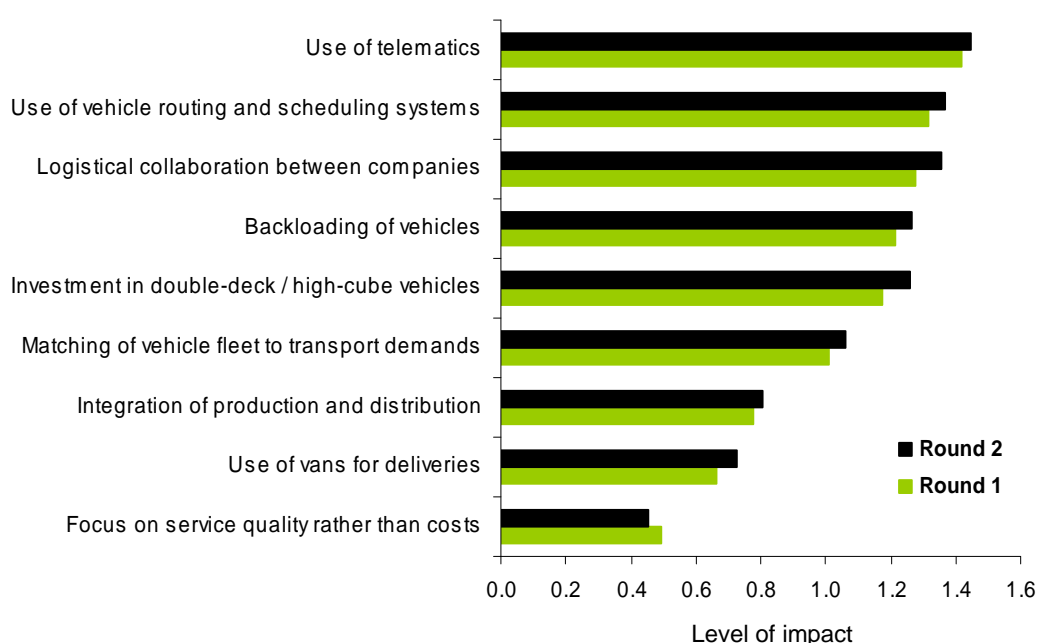


Figure 6.21. Functional factors affecting road freight demand (where -2 = much less important and 2 = much more important)

Almost all of the functional factors rated by the respondents are likely to bring significant savings in fuel consumption and emission levels in the short to medium term. Many of these best-practice measures, after all, require modest investment, are self-financing and carry little risk. As they are applied at the lowest and most flexible level in the decision-making hierarchy, they can allow companies to improve their environmental performance within fixed logistics structures or where commercial and operational constraints are imposed by a more powerful partner in the supply chain.

¹³ This may be also a result of decisions made at a higher, strategic level.

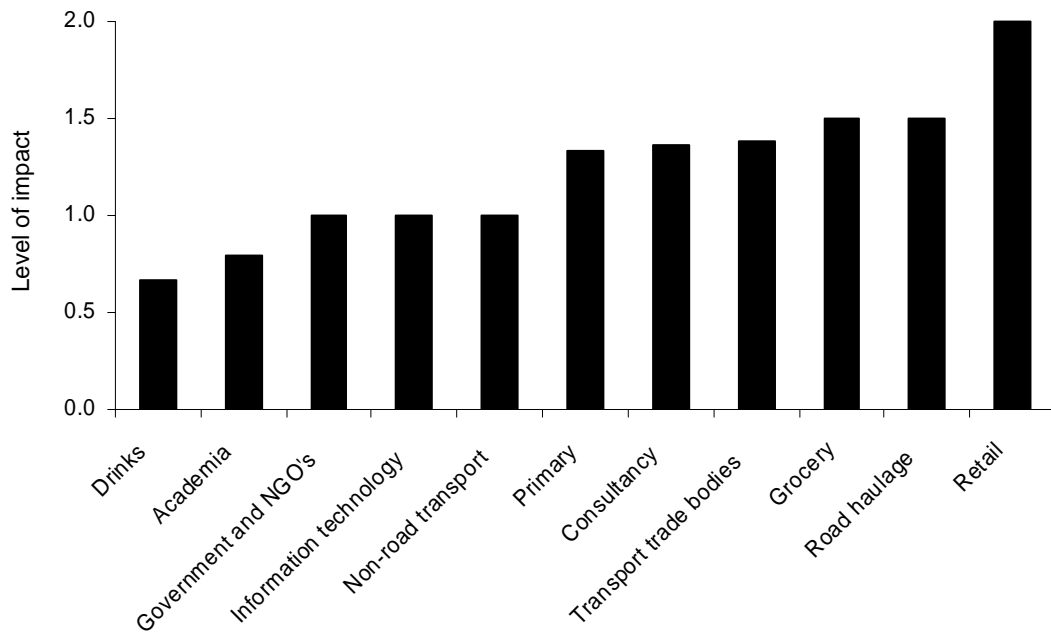


Figure 6.22. Differences in opinion on the uptake of double-deck / high-cube vehicles (where -2 = large reduction and 2 = large increase)

Analysis of driver and truck performance were amongst ‘other’ factors that the survey respondents thought are going to be important in the future. Two experts predicted also the creation of a national system for bi-directional load planning, something that one of them called ‘a centralised UK back-load desk’. Increased use of intermodal transport systems was also expected.

External factors

External factors – such as government regulations and tax policy, wider macroeconomic trends, market dynamics and advances in technology, are imposed on a company by the external environment. External factors will have a direct or indirect effect on virtually every key freight transport variable in the theoretical framework adopted in this thesis.

Fuel prices were perceived as the biggest threat to transport operations. However, increasing fuel prices can have a beneficial effect in reinforcing fuel efficiency initiatives among road freight users and reduction of the overall demand for road freight transport (Figure 6.23). The results from the European Commission funded HOP! project analysing direct and indirect impacts of long term oil price escalation on the European economy, suggest between 10 and 20% reduction in demand for freight transport if fuel prices were to rise to between 150 and 800 Euro/bbl in 2020, as compared to 70 Euro/bbl assumed in the reference case (Fiorello et al., 2008). If

combined with an extension of the European emissions trading scheme to transport and a switch to some types of alternative fuels¹⁴ high oil prices may induce significant reductions in freight-related CO₂ emissions. On the other hand, panellists also envisaged much greater use being made of online freight exchanges / load matching services by 2020, which will be likely to promote further reductions in empty running and exhaust emissions, thus have a positive impact on the road freight industry.

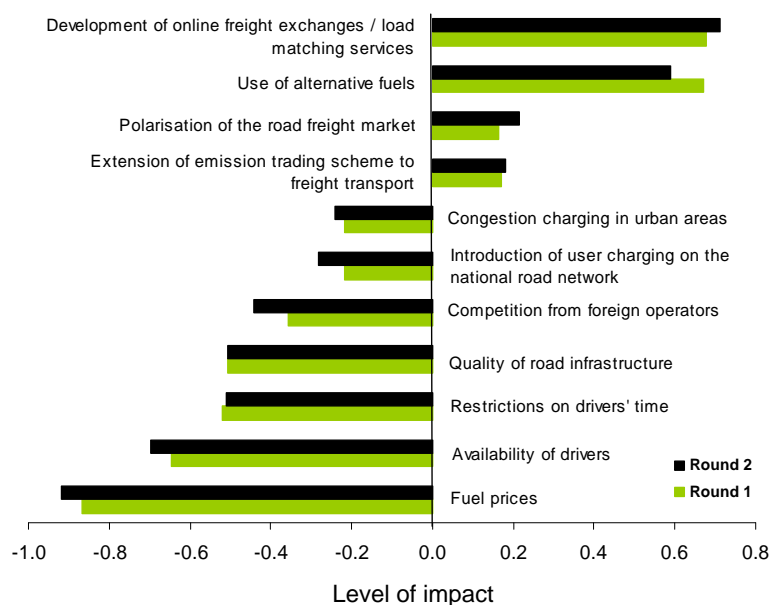


Figure 6.23. External factors affecting road freight sector (where -2 = large negative impact and 2 = large positive impact)

Infrastructure charges on the national road network as well as congestion charging in urban areas were judged as likely to have slightly negative consequences for the UK freight transport sector. However, there were statistically significant differences in perceptions of the impact of the user charging on the national road network across the different groups of experts. The panellists from primary manufacturing, retail, road haulage and information technology sectors believed that road charging presented a threat to the road freight system (-1.0, -1.0, -0.8 and -0.6). On the other hand, participants from consulting, drinks industry, academia, government, NGOs and transport trade bodies predicted that national road charging would have a slightly positive or neutral effect on the UK road freight transport in 2020 (0.4, 0.3, 0.0, 0.0 and 0.0) (Figure 6.24). From an environmental perspective, fiscal measures which reduce traffic congestion on both urban and rural roads are definitely beneficial, though they

¹⁴ Since the survey was completed, new scientific evidence has been published which suggests that, on a life-cycle basis, some biofuels are more carbon-intensive than conventional fossil fuels. Thus, EU and UK governments are currently reviewing their policies on biofuels.

may impose an additional economic burden on road transport operators using road infrastructure at busy times.

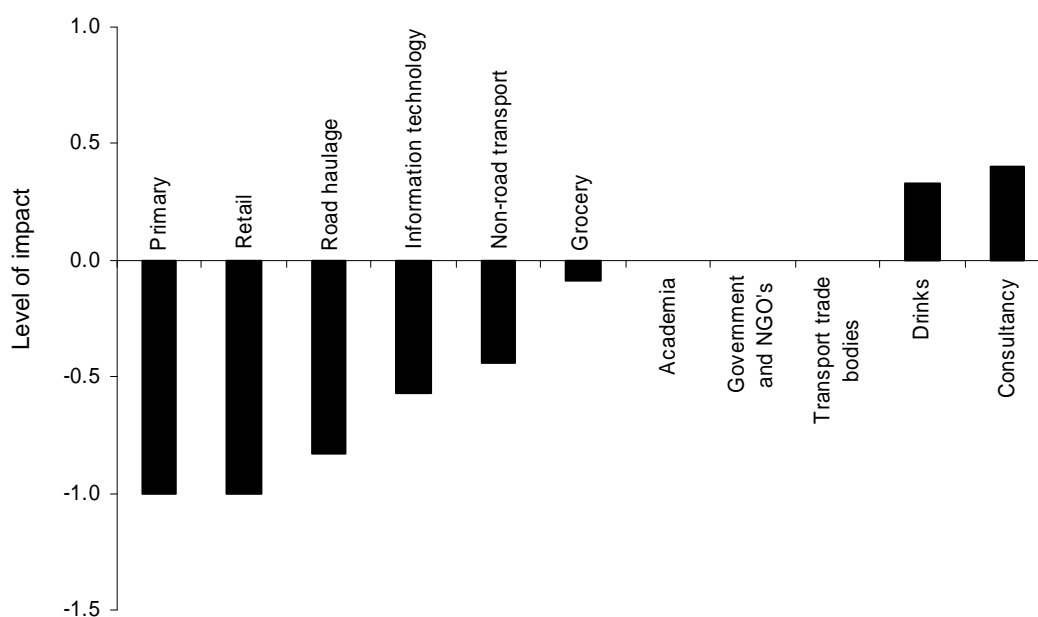


Figure 6.24. Projected impact of road charging on the road transport sector (where -2 = large negative impact and 2 = large positive impact)

Restrictions on drivers' time and a shortage of qualified drivers are expected to make management of delivery operations more difficult in 2020 resulting in a potential loss of flexibility and deterioration in performance. Driver availability was a particular concern of logistics service providers, retailers, and enablers (-0.9, -0.8 and -0.7) (Figure 6.25). Increased penetration of the UK haulage market by foreign operators was perceived as a moderate threat to the UK road freight market in 2020. At present, foreign operators, unlike their domestic counterparts, pay very little tax in the UK to compensate for their use of transport infrastructure and the related environmental impact (Piecnyk and McKinnon, 2007, Piecnyk et al. 2010). Current plans by the European Commission to internalise the environmental costs of freight operations across the EU should have corrected this anomaly by 2020 (European Commission, 2007b, Maibach et al., 2008).

Among 'other' factors suggested by the panellists congestion of the road network was indicated as likely to have a large negative impact on the industry up to 2020. Technological developments in vehicle propulsion systems enabling power sources other than liquid fuels (e.g. electric vehicles) were also considered important for the future of road freight transport, particularly in the urban areas.

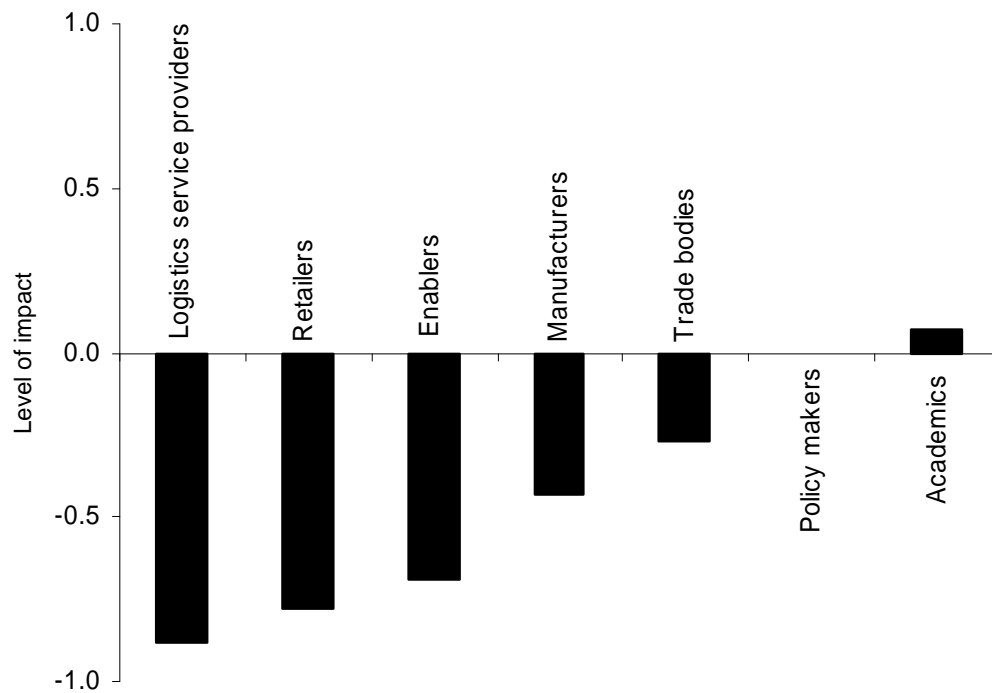


Figure 6.25. Projected impact of drivers' availability on the road transport sector (where -2 = large negative impact and 2 = large positive impact)

Product-related factors

Product-related factors affect the nature of the transport operation, i.e. mode choice, average length of haul and lading factor. They can be a result of internal decisions or be imposed by other partners in the supply chain (for example retailers may require product to be delivered in shelf-ready packaging).

Design of products and packaging impacts primarily on vehicle utilisation and thus on the environmental performance of logistics. Two contradicting trends were identified by panel members. Greater use of space-efficient packaging and handling equipment and increase in the amount of attention given to logistical requirements at the design stage of the product development process should improve vehicle fill and cut emissions. On the other hand, the projected increase in the use of shelf-ready packaging and imports of goods in store-ready format may undermine efforts to optimise vehicle utilisation and lead to increased fuel consumption and emissions (Figure 6.26). However, improvements in in-store efficiencies and on-shelf availability of goods makes shelf ready packaging amongst retailer which may be willing to trade-off these benefits against vehicle utilisation (Institute of Grocery Distribution, 2005).

Further miniaturisation of products and an increase in their value-density can also have offsetting effects. If products are smaller and lighter, more of them can be transported in one vehicle and so fewer journeys are needed. The higher the real value of goods, however, the greater will be the emphasis on customer service and inventory minimisation, possibly at the expense of vehicle utilisation.

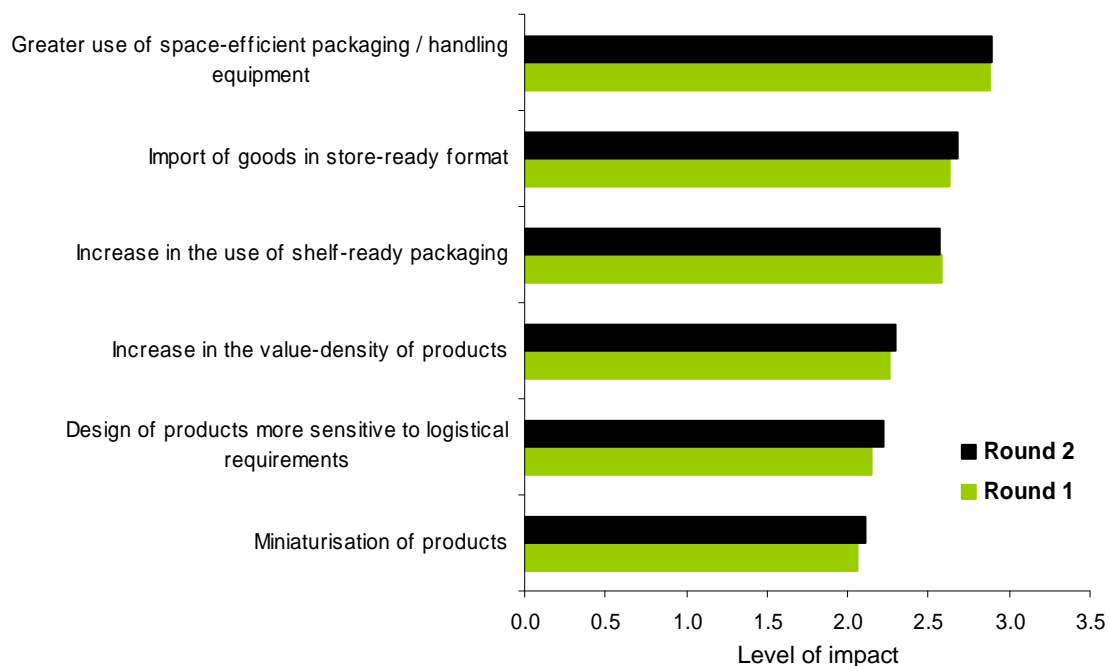


Figure 6.26. Product-related factors affecting road freight demand (where 0 = no impact and 4 = large impact)

Reduction of levels of consumption within Europe, decrease in overall levels of packaging or making packaging fully reusable / recyclable where having it is absolutely necessary, were amongst ‘other’ issues the Delphi panellist thought should be mentioned here.

6.2.4. Modal split

Modal shift is another important means of improving the sustainability of freight transport. By moving freight to less environmentally-damaging transport modes like rail or waterborne transport, significant savings in energy intensity and freight-related emissions can be achieved. Figure 6.27 shows the projected modal split in 2020 expressed as a percentage of the total tonne-kilometres moved.

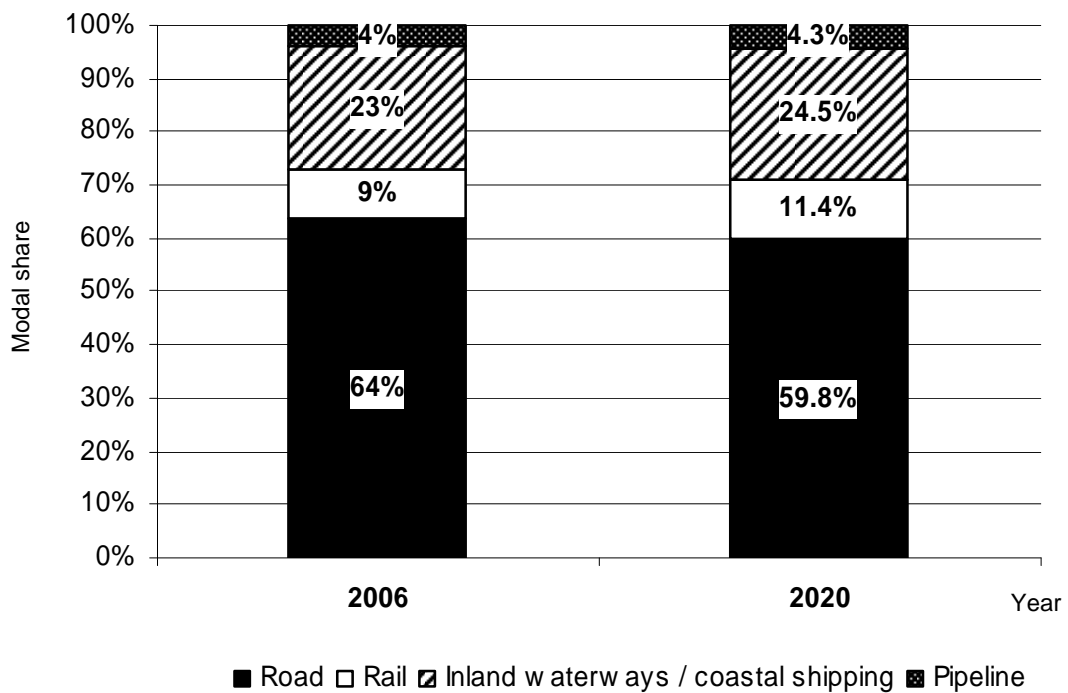


Figure 6.27. Modal split now and in 2020

As can be seen, there is going to be a modest positive change in modal split. The share of road freight transport is going to decline by over 4%, whereas other modes are going to gain market share. The biggest increase is expected in the case of rail freight (2.4%). The only currently available forecast of rail freight traffic growth predicts 26 – 28% growth in tonnage carried by rail by 2014/15 over the 2004/05 baseline (Network Rail, 2007). No projections for change in rail freight tonne-kms are made, hence it is very difficult to compare the Network Rail forecast with the Delphi results.

Nevertheless, road transport still remains by far the dominant mode and the net environmental benefit from modal shift may not be as great as desired by policy makers and pressure groups. According to the Delphi projections 60% of total tonne-kms will be transported by road. Based on the projections of the increase in the total tonne-kms, this is equivalent to 195 billion tonne-kms in 2020. These results show that it is important not only to encourage modal shift but also to focus on the road freight system in order to maximise its efficiency and minimise the levels of associated externalities.

Forecasts of the future share of airfreight were excluded from the survey. Domestically, aeroplanes carry currently only 0.01% of all tonne-kms in the UK (Department for Transport, 2009b). Even assuming a huge percentage growth, this mode's share is going

to be marginal. Airfreight, nevertheless, produces a high level of externalities per tonne-km. For example, domestic air cargo in the UK is estimated to emit 11 times more CO₂ per tonne-km than HGVs and 79 times more than rail freight (McKinnon, 2007b).

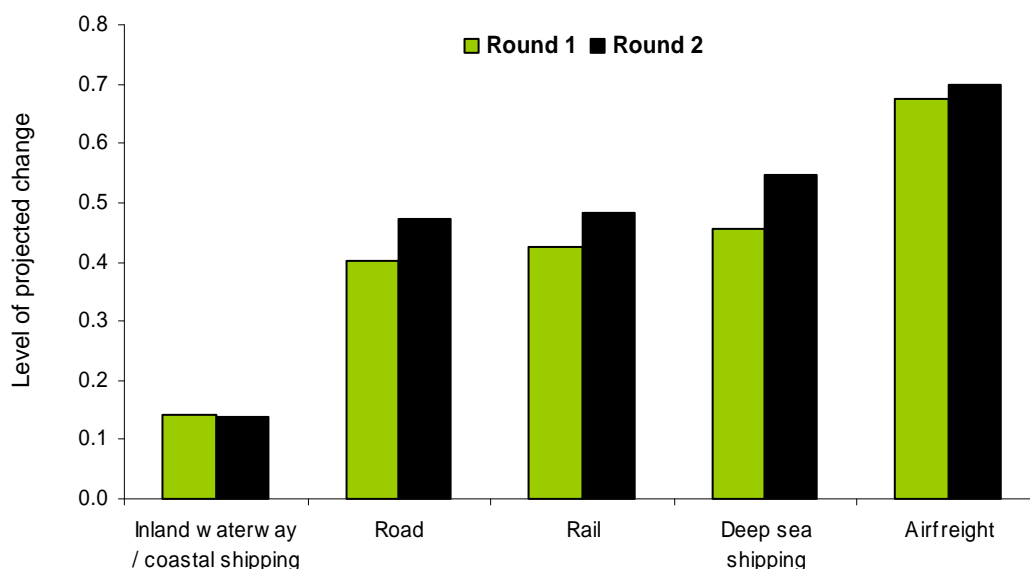


Figure 6.28. Projected change in value of goods carried by different modes (where -2 = large decrease and 2 = large increase)

The experts were also asked what changes they expect in the value of products moved by different transport modes (Figure 6.28). Overall increase in real value of products moved by all transport modes was predicted. However, the biggest increase in value was anticipated in case of goods delivered to the UK by air. From an environmental perspective this could be a positive development, as only the most valuable goods might be transported by air. If airfreight operators are required to internalise the external costs of their activities, for instance through taxing kerosene fuel, it will become uneconomic to move by air some of the lower value commodities currently moved by this mode. On the other hand, the value of goods moved by inland waterway or coastal shipping was predicted to stay at the current level. This suggests that the experts were very doubtful about initiatives aiming to shift higher value-density products onto these modes. Bulk, low-value goods are going to remain the main products carried by inland waterway and coastal shipping services. A moderate increase in value was expected for goods transported by road, rail and deep-sea shipping.

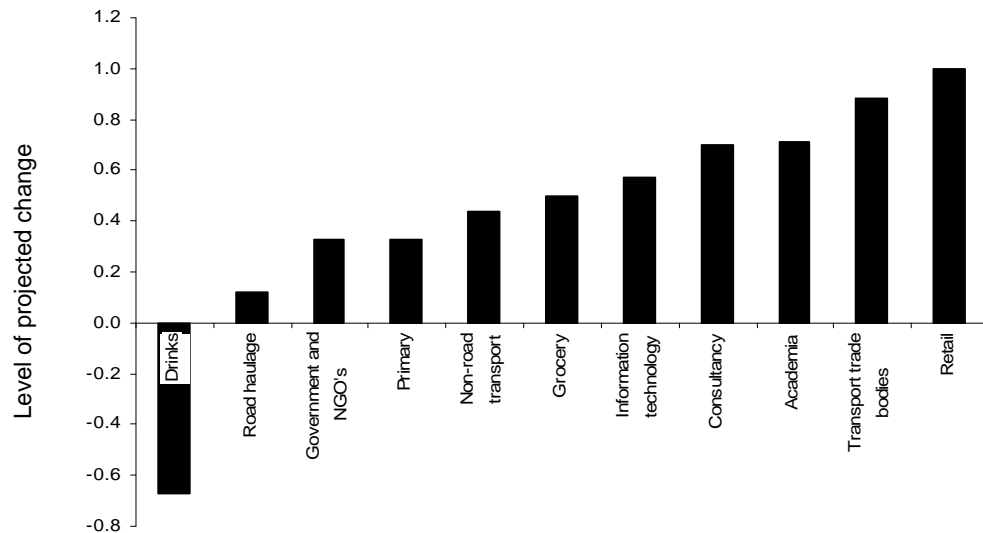


Figure 6.29. Differences in opinion on the change of value of goods carried by rail (where -2 = large decrease in value and 2 = large increase in value)

There was, nevertheless, a disagreement about the projected change in the real value of goods transported by rail amongst panellists representing different industry sectors. Experts from the retail sector and transport trade bodies expected a significant increase in the real value of products transported by rail (1.0 and 0.9). A decrease in the real value of products moved by this mode was predicted by panellists from the drinks industry (-0.7) (Figure 6.29).

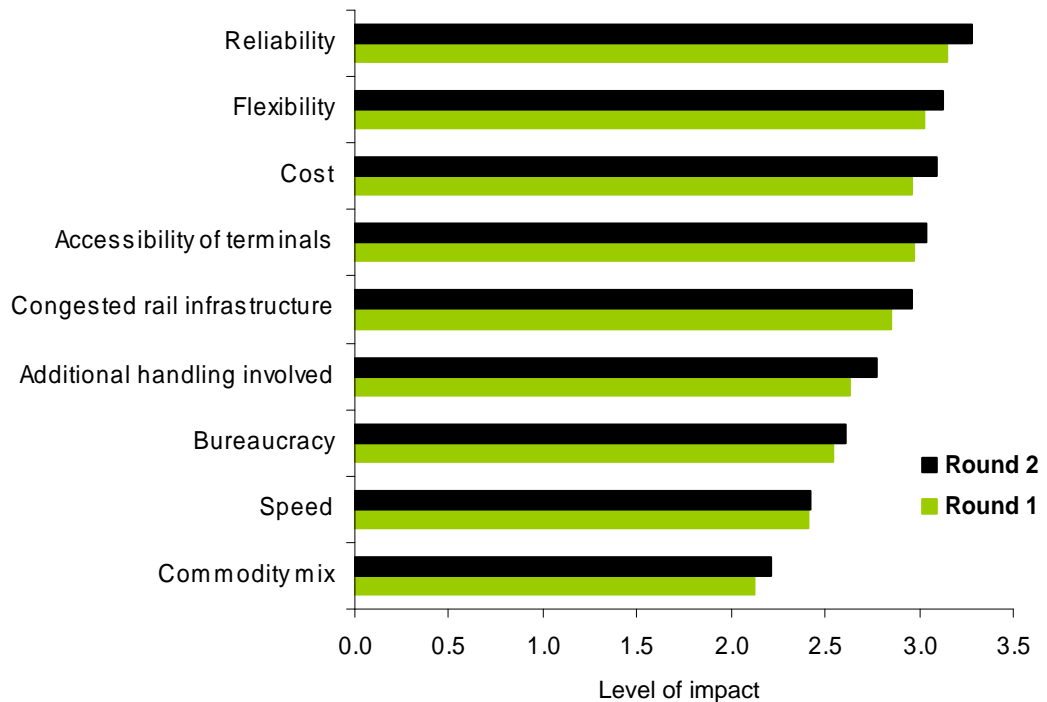


Figure 6.30. Factors influencing the amount of cargo carried by rail in 2020 (where 0 = no impact and 4 = large impact)

With regard to rail transport, reliability, flexibility, cost and accessibility of terminals were identified as the major factors influencing the amount of freight carried by 2020. Speed, commodity mix and bureaucracy were least important in comparison to other factors (Figure 6.30).

The analysis of the data has shown statistically significant differences in opinions on the impact of additional handling associated with using rail services between panellists representing different links in the supply chain. Experts from academia and policy making or influencing groups were less concerned about the problem of additional handling required to transport goods by rail (2.2 and 2.5), whereas representatives of trade and manufacturing organisations were most sceptical (3.4 and 3.0 respectively).

The experts added also that emergence of true integrated cross-Channel Tunnel rail links, provision of door-to-door rather than terminal-to-terminal services and availability of solutions to handle smaller loads would aid the rail's share of the freight market. Security concerns were identified as one of the factors likely to prevent higher value goods from being send by rail.

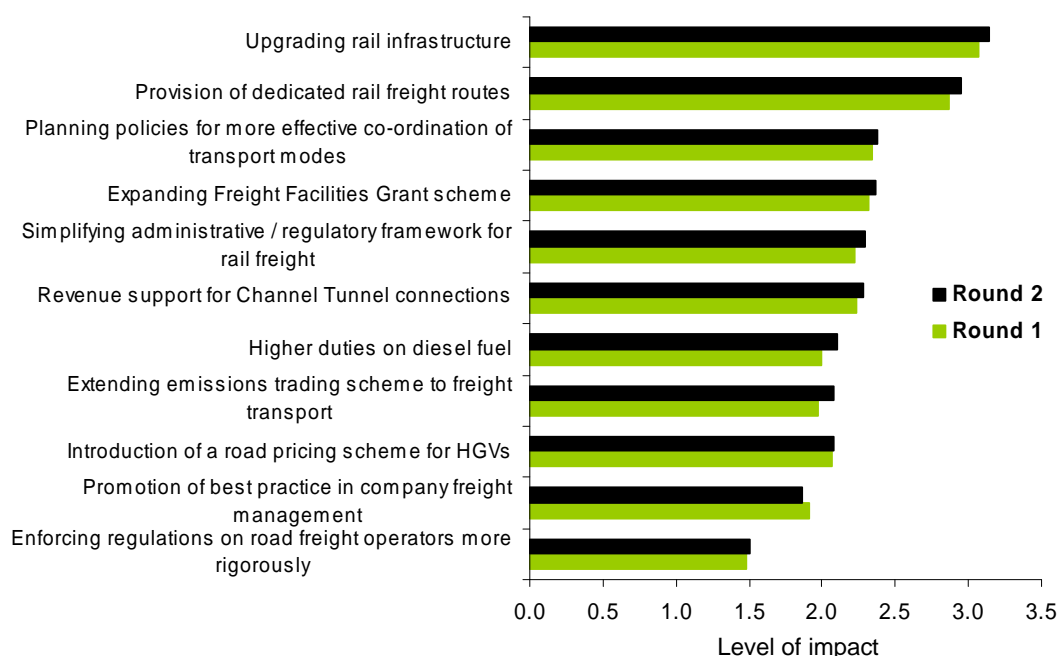


Figure 6.31. Efficiency of potential measures to increase rail's share of freight market (where 0 = no effect and 4 = very effective)

According to the experts, upgrading rail infrastructure, provision of dedicated freight lanes and simplifying the administrative / regulatory framework for rail freight would be

most effective means of increasing rail's share of the UK freight market. Encouraging modal shift by enforcing regulations on road freight more rigorously, increasing taxes on diesel fuel or extending emission trading scheme to freight transport were accorded much less importance (Figure 6.31). Similar conclusions emerged from a recent study commissioned by the Scottish Executive (Flanders and Smith, 2007).

The amount of cargo carried by coastal shipping up to 2020 will be largely determined by the cost of using this transport mode. Accessibility of ports and congested infrastructure may be the key factors inhibiting an increase in coastal shipping's share of the freight market. Reliability of this transport mode was considered to be more important than its speed. Bureaucracy and additional handling associated with using coastal shipping were not considered as major obstacles (Figure 6.32).

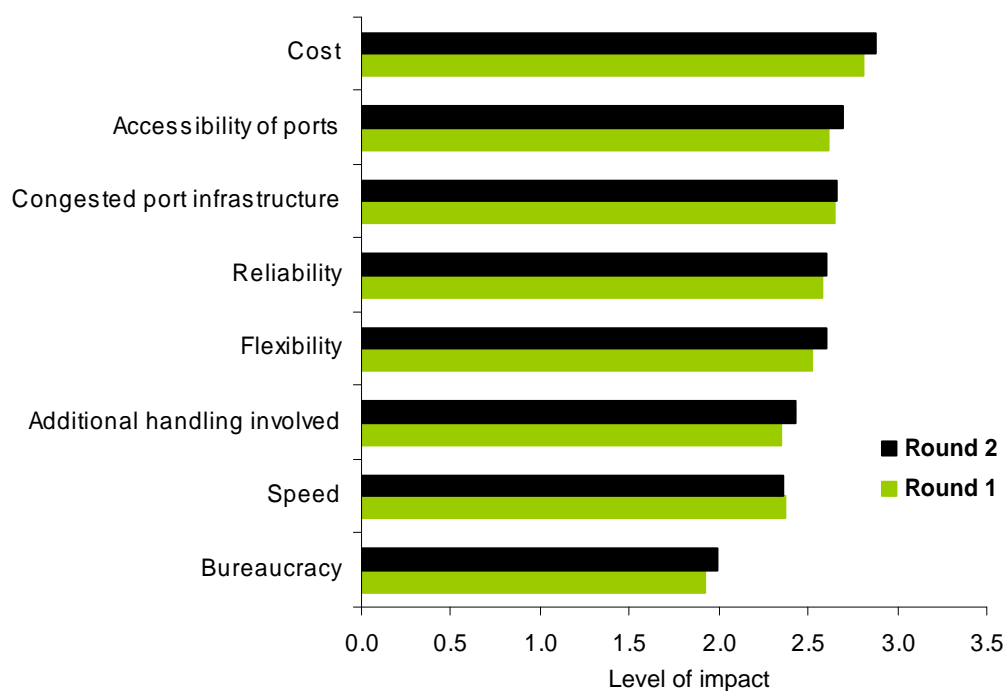


Figure 6.32. Factors influencing the amount of cargo carried by coastal / short-sea shipping in 2020 (where 0 = no impact and 4 = large impact)

In order to promote the use of coastal shipping, the UK Government should focus its efforts on providing better infrastructure and consider expansion of the Waterborne Freight Grant scheme. New policies are needed to support more effective co-ordination of transport modes. As in the case of promoting modal shift to rail, more rigorous enforcement of regulations on road freight operators, extension of emission trading scheme to freight transport or raising taxes on diesel fuel were considered to be only

moderately effective means of encouraging businesses to use coastal shipping more extensively (Figure 6.33).

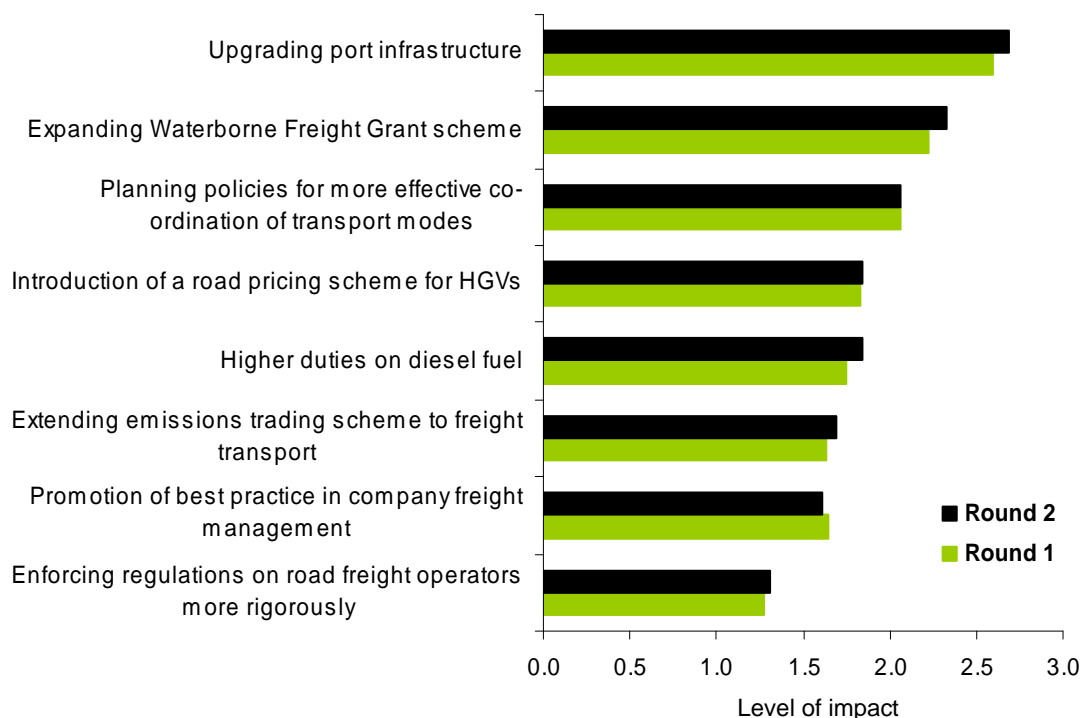


Figure 6.33. Efficiency of potential measures to increase coastal / short-sea shipping's share of freight market (where 0 = no effect and 4 = very effective)

Overall, the panellists predicted a slight relaxation of the constraints on using rail and shipping services by 2020. Furthermore, constraints on coastal shipping services are predicted to ease to a slightly larger extent than those on rail (Figure 6.34).

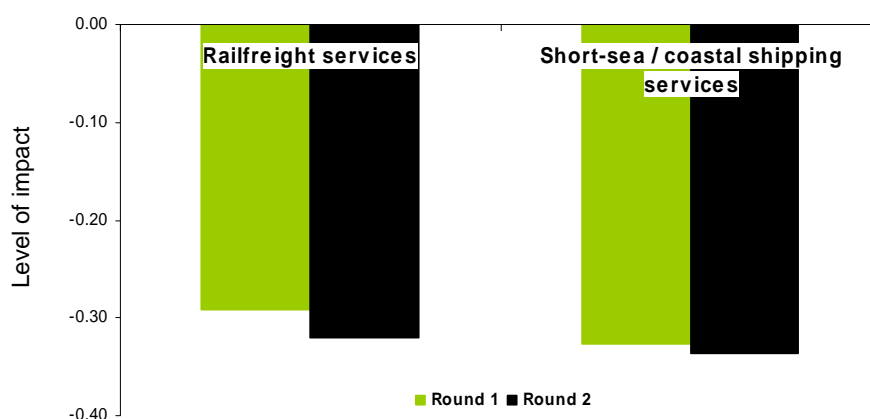


Figure 6.34. Projected changes in the constraints on using rail and shipping services (where -2 = constraints significantly easing and 2 = constraints significantly tightening)

6.2.5. Fuel management

According to the Delphi panellists, additional environmental benefit will accrue from increases in fuel efficiency (expressed as vehicle-kms per litre of fuel consumed) and a reduction in the carbon intensity of fuel (i.e. CO₂ emitted per litre of fuel) (Figure 6.35).

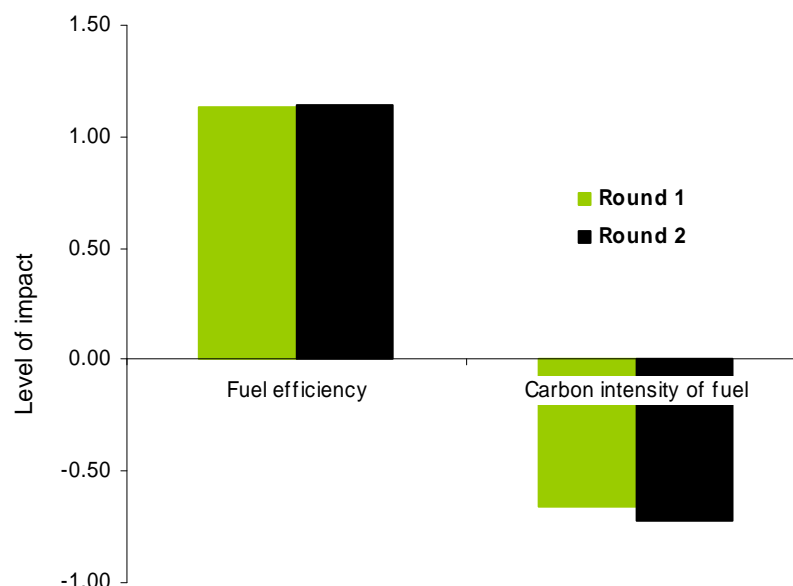


Figure 6.35. Projected changes in efficiency and carbon intensity of fuel (where -2 = large decrease and 2 = large increase)

Vehicle design, engine performance, information technology (telematics, vehicle routing software) and training schemes for fuel efficient driving were identified as the main drivers of improved fuel efficiency (Figure 6.36). The greatest external pressure on companies to reduce their fleets' fuel consumption will be high fuel prices. Relative to other factors, dissemination of best practice in fuel management was given a low rating. Overall, the results suggest that technological developments are going to play the main role in improving fuel efficiency. This is consistent with the findings of a report on opportunities to reduce CO₂ emissions from logistics and freight transport developed via a number of workshops with the World Economic Forum's Logistics and Transport Industry Partners (Doherty and Hoyle, 2009). In order to achieve synergy of efforts, the promotion of best practice should focus on the dissemination of knowledge on available technological solutions to reduce fuel consumption.

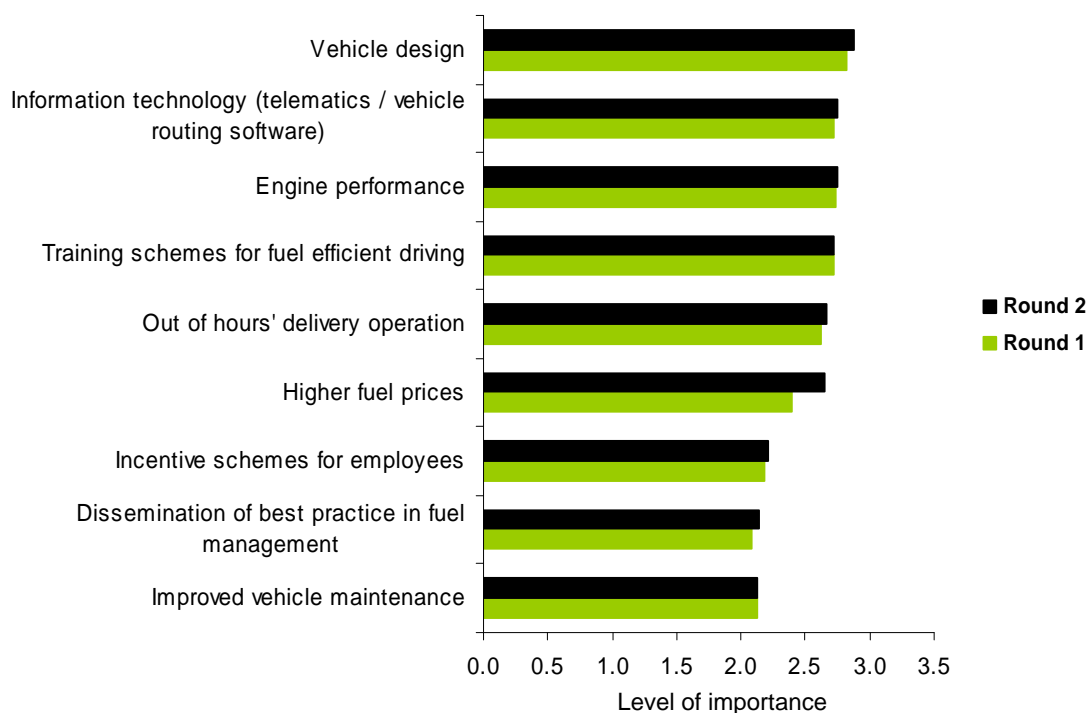


Figure 6.36. Projected importance of fuel efficiency measures (where 0 = no importance and 4 = very important)

Although all participants perceived higher fuel prices as an significant factor encouraging companies to improve their fuel efficiency, policy makers, academics and retailers regarded it as more important (3.3, 3.1 and 3.0) than representatives of trade organisations and manufacturers (2.1 and 2.1) (Figure 6.37). This may mirror the willingness of policy makers to use fuel taxes as a policy lever.

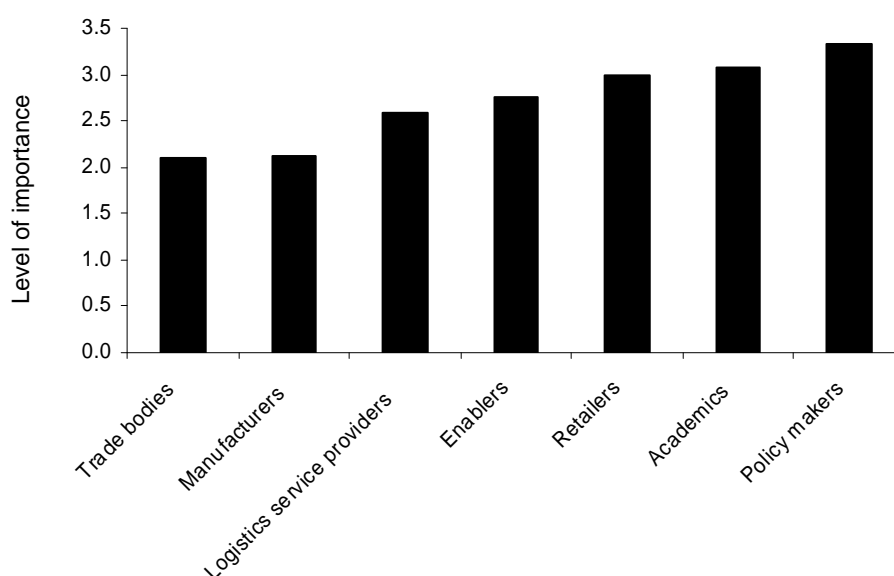


Figure 6.37. Projected impact of higher fuel prices on improving the fuel efficiency (where 0 = no importance and 4 = very important) – differences in opinion by type of organization represented

Freight only routes, IT systems to support more complex fleet management and alternative fuels were indicated as ‘other’ factors that would support companies in effective fuel management by 2020.

6.2.6. Other comments

In the last question, the participants were given an option to add comments on any other issues they found important and that had not been addressed in the questionnaire. One of the purposes of this question was to enable experts to express their views on possible future breakthrough developments that may not have been anticipated at the questionnaire design stage. This section presents a summary of these additional comments.

Quite a few comments regarded the need for an integrated approach by Government to sustainable logistics. Potential policy measures should be well planned and comprehensive in promoting sustainability in all its aspects simultaneously, i.e. economic, social and environmental dimensions. It was also felt that infrastructure-related bottlenecks may impair the logistics industry efforts to become more environmentally-friendly and these should be addressed by the policy makers first. It was suggested that *“policy towards congestion in terms of road capacity, town planning and work patterns, is extremely important”*.

Other frequently mentioned points concerned the distribution of decision making power in the supply chain and how the demands from final consumers or retailers affect freight transport as *“the servant of that demand”*. One of the participants suggested that a new tax should be imposed on companies responsible for increasing carbon footprint of the industry in order to internalise the extra environmental burden their actions cause. *“This questionnaire is focused on the operations rather than the customers / the retailers that drive demand down the supply chain, to their suppliers and the suppliers’ hauliers. The retailers are focused on reducing stock coupled with squeezing prices and increasing the service they receive from their suppliers. This, in turn, leads to the retail suppliers squeezing their suppliers including the hauliers. It also leads to smaller more frequent deliveries which results in greater carbon emissions. The retailers need to be responsible for their part in the whole supply chain, not just the element that they are directly responsible for. This should materialise in a ‘carbon tax’ that forces the retailers to invest a proportion of their ludicrous profit margins back into improving the*

environment". Customer behavioural change and consumption habits were also considered crucial factors to making logistics and freight transport more sustainable.

Although survey results suggest that subcontracting of non-core activities is expected to remain important at least up to 2020, there were opinions that environmental concerns will force companies to address their attitude to transport, which may even result in the reversal of the outsourcing trend. As one of the panelists explained: *"I would not be surprised to see a cyclic shift of bringing transport back in-house. This could have the effect of improving the focus on the 'greening' of freight transport, as the nearer it gets to the end customer the more direct the pressure will be to improve both environmental impacts and cost"*.

In general, looking at the common themes in the majority of the comments it was felt that *"a combination of infrastructure, training and visibility tools are the 'triple whammy' required to significantly impact the efficiency of the freight logistics industry"*. All points raised made a useful contribution and confirmation of survey results. However, none of the comments was surprising or unanticipated to a degree which would suggest it can form a base for constructing an additional 'wild card' scenario to be modelled in the next phase of the research project, as done by Von den Gracht (2008).

6.2.7. Analysis of the correlation between Delphi questionnaire variables

As mentioned above, Pearson's correlation coefficient analysis was conducted in order to investigate whether there were any relationships between respondents' opinions on the future direction of trends and the magnitude of various effects. This analysis aimed also to test validity of the overall survey findings by assessing if there are significant correlations between variables that one would expect to co-vary. In order to calculate correlation coefficients the data needs to be measured at least at the ordinal level. 18 questions fulfil this assumption, and because most of them are multi-faceted, 115 variables were tested for relationships between them using a two-tailed test. The two-tailed test should be used when a linear relationship is expected but the direction of this relationship is not predicted (Ho, 2006). 1255 of 6555 (i.e. 19%) correlation coefficient values were significant at either 5% or 1% confidence level. It is important to emphasise that, due to the large number of correlations undertaken, caution should be exercised when interpreting significant but small values (Field, 2005).

Analysis of the strongest correlations between variables

In this section, the focus is on 20 strongest relationships, i.e. combinations where $|r| \geq 0.6$, the average between levels recommended by Cohen and Holliday (1982) and Field (2005) (Table 6.8).

The strongest linear relationship was detected between experts' opinion on the potential impact of user charging on the national road network (Q5C) and congestion charging in urban areas (Q5D) on the UK road freight transport by 2020 ($r = 0.833$, $p < 0.01$). This suggests that those who object to road charging schemes, object to them at different geographical scales. As the average responses to both questions suggested negative perception of road charging impact on the UK road freight transport (-0.3 and -0.2 on a -2 to 2 scale for national and urban congestion charging respectively), there seems to be a general opposition to road charging initiatives.

No.	Question 1	Question 2	r	p
1	Q5C	Q5D	0.833	0.000
2	Q14J	Q16H	0.830	0.000
3	Q11B	Q11D	-0.806	0.000
4	Q14G	Q16E	0.763	0.000
5	Q16B	Q16F	0.748	0.000
6	Q14B	Q14H	0.741	0.000
7	Q14H	Q16F	0.717	0.000
8	Q14I	Q16G	0.695	0.000
9	Q18F	Q18I	0.692	0.000
10	Q15C	Q15E	0.677	0.000
11	Q5A	Q5B	0.660	0.000
12	Q14H	Q14I	0.653	0.000
13	Q16F	Q16G	0.646	0.000
14	Q5D	Q5G	0.641	0.000
15	Q14B	Q16B	0.620	0.000
16	Q14H	Q16G	0.620	0.000
17	Q14H	Q16B	0.615	0.000
18	Q6D	Q6E	0.613	0.000
19	Q18H	Q18I	0.606	0.000
20	Q18E	Q18F	0.604	0.000

Table. 6.8. Pearson's correlation coefficients, $|r| \geq 0.6$

The greatest number of strongest correlations was detected **between** responses to questions on the likely effectiveness of potential Government measures in increasing rail's and coastal / short sea shipping's share of the UK freight market (Q14 and Q16). This suggests that the majority of respondents predicted that the same sets of policy measures would be effective in promoting different alternative modes. There was a very

strong positive relationship between predicted effects of enforcing regulations on road freight traffic operators more rigorously and the increase in rail's (Q14J) and coastal / short sea shipping's (Q16H) share of the domestic freight market ($r = 0.830$, $p < 0.01$). Likely impact of planning policies on the effective co-ordination of transport modes was also significantly correlated for both alternative transport modes (Q14G and Q16E, $r = 0.763$, $p < 0.01$). There was a strong correlation between predicted effectiveness of higher fuel duties in increasing rail's and water's shares (Q14H and Q16F, $r = 0.748$, $p < 0.01$). Q14H was also significantly correlated with perceived effects of extending emission trading scheme to freight transport (Q16G), and with introduction of a road pricing scheme for HGVs (Q16B) on volumes transported by coastal / short sea shipping ($r = 0.620$ and $r = 0.615$, $p < 0.01$, respectively). There was a strong positive relationship between the expected effectiveness of extending the emission trading scheme to freight transport in encouraging shift to rail (Q14I) and waterborne modes (Q16G) ($r = 0.695$, $p < 0.01$). Those respondents who thought that the introduction of road pricing would be an effective way of promoting modal shift to rail (Q14B) were of similar opinion in the case of waterborne freight transport (Q16B) ($r = 0.620$, $p < 0.01$).

Strong linear relationships also emerged **within** both questions regarding means of promoting modal split. Experts' opinions on the effectiveness of higher taxation of diesel fuel (Q14H) and introduction of a road charging scheme (Q14B) in encouraging more goods being moved by rail were significantly correlated ($r = 0.741$, $p < 0.01$). Similarly, effects of an increase in fuel duties (Q14H) were positively related to extending emission trading scheme to goods transport (Q14I) ($r = 0.653$, $p < 0.01$). There was a strong correlation between the predicted impact of introduction of a road pricing scheme for HGVs (Q16B) and enforcing regulations on road freight operators more rigorously (Q16H) on the amount of freight moved by waterborne transport ($r = 0.748$, $p < 0.01$). Also, with respect to coastal / short sea shipping, the likely effectiveness of the imposition of higher taxation rates on diesel fuel (Q16F) was significantly related to predicted impacts of extending emission trading scheme to freight transport (Q16G) ($r = 0.646$, $p < 0.01$). Further, there was a significant relationship between the perceived impact of congested port infrastructure (Q15C) and the accessibility of ports (Q15E) on the amount of goods carried by coastal / short sea shipping by 2020 ($r = 0.667$, $p < 0.001$).

Interesting correlation coefficients were detected between experts' predictions on shares of different transport modes in 2020 (expressed in terms of the percentage of tonne-kms carried). Expected share of road transport (Q11D) was in stronger negative correlation with predicted share of inland waterways / coastal shipping (Q11B) ($r = -0.806$, $p < 0.01$) than with likely proportion of freight traffic moved by rail (Q11C) ($r = -0.583$, $p < 0.01$). At the same time, there was no significant relationship detected between the expected shares of waterborne and rail freight transport (Q11B and Q11C), hence experts' opinions on future shares of these two were independent on each other.

With respect to the likely effectiveness of different means of improving the fuel efficiency of freight transport operations by 2020 (Q18), the following were amongst the 20 strongest correlation coefficients. Engine performance (Q18I) was in a positive relationship with vehicle design (Q18F) ($r = 0.692$, $p < 0.01$) and improved vehicle maintenance (Q18H) ($r = 0.606$, $p < 0.01$). Vehicle design (Q18F) was also significantly correlated with information technology i.e. solutions such as telematics or vehicle routing software (Q18E) ($r = 0.604$, $p < 0.01$). Further, all measures discussed here achieved very similar average scores, as shown in the previous section. This suggests that these different options may be grouped under one common theme of technological developments.

Strong correlations occurred also between various external factors likely to affect road freight transport in the UK by 2020 (Q5). Restrictions of drivers' time (Q5A) were significantly related to availability of drivers (Q5B) ($r = 0.660$, $p < 0.01$). Thus, it can be concluded that, in the opinion of majority of Delphi panellists, an impact of both driver-related factors will be of similar, most likely negative – based on an average score – direction and magnitude. Hence, these two factors are likely to be mutually reinforcing, creating additional problems for road freight operators in the future. Also, the likely impact of congestion charging in urban areas (Q5D) was positively correlated with that of fuel prices (Q5G) ($r = 0.641$, $p < 0.01$). Linking this back to the correlation between experts' opinions on road / congestion charges in urban and inter-urban areas, again it is possible to group all these variables under one common theme such as for example financial incentives.

Regarding expected changes in product and packaging design by 2020 (Q6), the extent to which miniaturisation of products is likely to occur (Q6D) was significantly

correlated with expected increase in the value-density of products (Q6E) ($r = 0.613$, $p < 0.01$). Combining this with an average score for both variables (2.1 and 2.3, respectively) it can be concluded that the majority of experts were of the opinion that in the future products are going to become smaller and more valuable at the same time. This should help companies to withstand future increases in transport costs.

Extending the correlation coefficient analysis to the 49 strongest linear relationships with $|r| > 0.5$ (as recommended by Field, 2005), most of them occur between variables listed in Q5, Q11, Q14, Q16 and Q18, i.e. within further variables forming questions discussed above. This illustrates the strong rationale underpinning experts' forecasts, where variables that can be expected to contribute to a particular effect (for instance promotion of modal shift or improvements in fuel efficiency) are significantly correlated with each other.

Analysis of the main factors correlated with the key logistics variables

The next step of the correlation analysis involved checking which variables are in significant linear relationships with experts' forecast of the key freight transport parameters, i.e. the degree of decoupling of GDP and road tonne-kms, changes in average length of haul, handling factor, lading factor, empty running, fuel efficiency, carbon intensity and modal split. Here, Pearson's correlation analysis was a useful technique to identify how experts' opinions on future changes in key variables were correlated with their likely impacts.

1. The predicted pace of **growth in tonne-kms as compared to GDP up to 2020** was significantly correlated with 12 other variables, with the three strongest being the degree of expansion of the market areas of UK businesses (Q2D) ($r = 0.297$, $p < 0.01$), effectiveness of promotion of best practice in company freight management in encouraging modal shift to coastal / short sea transport (Q16D) ($r = 0.276$, $p < 0.01$) and the extent to which the amount of freight carried by coastal / short-sea shipping by 2020 is likely to be affected by bureaucracy (Q15G) ($r = 0.270$, $p < 0.01$). While the first and third correlations suggest that an expansion of market areas and stronger constraints on using alternative modes of transport are likely to result in faster growth of road tonne-kms, the second one is more difficult to explain. More effective means of promoting

modal shift should result in slower growth in tonne-kms, thus a negative relationship should be expected.

2. There were six significant correlations between the expected change in the **average length of haul** (Q9A) and six other variables. The strongest included predicted change in the carbon intensity of fuel (Q10B) ($r = 0.344$, $p < 0.01$), development of urban consolidation centres (Q1I) ($r = -0.317$, $p < 0.01$), centralisation of inventory (Q1C) ($r = 0.256$, $p < 0.05$) and integration of production and distribution (Q4C) ($r = -0.254$, $p < 0.05$). The suggestion that those who predicted shorter average length of haul were more likely to believe that carbon intensity of fuel is going to be reduced by 2020 is difficult to explain and may be a coincidence.
3. Expected changes in **handling factor** for goods moved by road (Q9B) were significantly related to 14 other variables, including predictions on changes in value of products moved by road (Q12Q) ($r = -0.285$, $p < 0.01$), effectiveness of higher taxes on diesel fuel in promoting modal shift to rail (Q14H) and waterborne transport (Q16F) ($r = -0.272$ and $r = -0.265$, $p < 0.05$) and fuel efficiency (Q10A) ($r = -0.269$, $p < 0.05$).
4. There was a significant negative relationship between expected **lading factor** (Q9C) and empty running (Q9D) ($r = -0.399$, $p < 0.01$). This means that experts who believed that empty running is going to decrease by 2020, were more likely to indicate further improvements in lading factor. Other factors correlated with predicted changes in lading factor were road's share of freight market (Q11D) ($r = -0.286$, $p < 0.01$), uptake in investment in double-deck / high-cube vehicles (Q4E) ($r = 0.276$, $p < 0.01$) and expected growth in the total tonne-kms carried by all modes in 2020 (Q8) ($r = 0.274$, $p < 0.01$). While, the two last correlations do not seem surprising, the negative relationship between changes in lading factor and the amount of tonne-kms moved by road is more difficult to explain. It suggests that with diminishing share of road transport companies are likely to operate their fleets more efficiently. Overall, the likely change in lading factor was correlated with 25 other variables.

5. The predicted level of **empty running** in 2020 (Q9D) was significantly correlated with 27 variables. The strongest relationship occurs with the likely extent of matching of vehicle fleet to transport demands (Q4D) ($r = -0.444$, $p < 0.01$), the level of logistical collaboration between companies (Q4B) ($r = -0.440$, $p < 0.01$) and backloading (Q4G) ($r = -0.411$, $p < 0.01$), use of vehicle routing and scheduling systems (Q4H) ($r = -0.380$, $p < 0.01$) and development of online freight exchanges / load matching services (Q5H) ($r = -0.365$, $p < 0.01$). All these correlations were expected to occur.
6. Expected change in **fuel efficiency** (Q10A) was significantly correlated with 11 variables and developments in carbon intensity of fuel (Q10B) with 19 of them. Experts who predicted higher increase in fuel efficiency, expected also a larger extent to which accessibility of terminals is going to impact the amount of goods moved by rail by 2020 (Q13E) ($r = 0.293$, $p < 0.01$). The relationship between these two is difficult to explain but it needs to be noted that the fact that there is a significant correlation between them does not imply causality and it only illustrates certain links in experts' forecasts. Fuel efficiency was also negatively correlated with handling factor (Q9B) ($r = -0.269$, $p < 0.05$). This, most likely, mirrors experts' view that as the number of handling points increases the distance between them decreases resulting in shorter and less fuel efficient truck movements. This is confirmed by next, in terms of its strength, correlation between expected changes in fuel efficiency and extent of centralisation of production by 2020 (Q1A) ($r = 0.244$, $p < 0.05$). As production facilities become more centralised, distances between them and other nodes in the supply chain tend to increase. Adding this to the likely benefits of economies of scale from centralised manufacturing results in more long-haul movements by fully loaded vehicles. This, in turn, should lead to the overall improvements in fuel efficiency. Further, fuel efficiency was positively correlated with the envisaged impact of alternative fuel on the UK road freight transport (Q5K) ($r = 0.243$, $p < 0.05$). This indicates that panellists who thought that alternative fuels will have a negative impact on freight transport operations by 2020 predicted also decrease in fuel efficiency of HGVs over this period, i.e. the majority of the participants assumed that alternative fuels will have less energy content. Similar views were expressed during focus group sessions, as discussed in the previous Chapter.

7. There was a significant positive relationship (although no causal links) between the expected changes in **carbon intensity** and share of pipeline transport of the freight market (Q11A) ($r = 0.354$, $p < 0.01$), changes in average length of haul by road (Q9A) ($r = 0.344$, $p < 0.01$), uptake in logistical collaboration between companies (Q4B) ($r = -0.327$, $p < 0.01$) and importance of higher fuel prices in improving the fuel efficiency of freight transport operations (Q18B) ($r = -0.324$, $p < 0.01$).
8. With respect to **modal split**, as mentioned above, the projections on the future share of road of the UK freight transport market (Q11D) were strongly correlated with those on future share of waterborne modes (Q11B) and to a lesser extent with those on share of railfreight (Q11C) and pipeline (Q11A) ($r = -0.806$, $r = -0.583$, $r = -0.328$, $p < 0.01$). The forecast of future shares of road and rail were correlated with 27 variables each, share of inland waterways / coastal shipping with 10 and share of share of pipeline with 12 other variables.
9. The projected share of **road** was significantly correlated with expected changes in the value of products moved by this mode (Q12A) ($r = 0.464$, $p < 0.01$), i.e. participants who thought the share of road in the UK freight transport market is going to increase were also likely to expect a higher growth in the value of goods carried by lorries. Availability of drivers (Q5B) and restrictions on drivers' time (Q5A) were, on the other hand, negatively correlated with projected share of road ($r = -0.380$, $r = -0.364$, $p < 0.01$).
10. Future change in the share of **rail** was significantly related to perceived degree of relaxation / tightening of the constraints on using its services (Q17A) ($r = -0.506$, $p < 0.01$), i.e. the more the constraints were expected to ease by 2020, the higher the anticipated share of this mode was. The panellist who expected the share of rail to increase, were also more likely to express a view that enforcing regulations on road freight operators more rigorously will be an effective means of encouraging mode shift to more sustainable modes i.e. to waterborne (Q16H) and rail transport (Q14J) ($r = 0.460$, $r = 0.408$, $p < 0.01$).
11. There was a significant positive relationship between the forecast share of **inland waterways / coastal shipping** with anticipated change in the value of

goods moved by this mode (Q12C) ($r = 0.423$, $p < 0.01$), suggesting that those who expected the share of waterborne transport to increase, believed also that in the future this mode will be able to capture more of the higher-margin traffic. On the contrary, experts who projected increase in the value of products moved by HGVs (Q12A), expected inland waterways / coastal shipping to maintain lower share of the domestic freight market ($r = -0.387$, $p < 0.01$). Also, the expected uptake of backloading practices in the road freight sector (Q4G) was negatively correlated with expected change in the amount of goods moved by waterborne transport ($r = -0.338$, $p < 0.01$), suggesting that efficiency improvements in road transport operations are likely to limit future shift to alternative modes.

12. Forecast share of **pipeline** transport was positively correlated with future application of JIT principle (Q3B) ($r = 0.373$, $p < 0.01$) and predicted changes in carbon intensity of fuel (Q10B) ($r = 0.354$, $p < 0.01$) while in a negative linear relationship with opinions on importance of localised sourcing of supplies by 2020 (Q2C) ($r = -0.268$, $p < 0.01$). Although, these correlations may seem surprising, it needs to be taken into account that pipeline transport tends to be used by specialised supply chains (i.e. petroleum products supply chains) and is rarely an option to be considered in a typical transport system decision-making process. Thus, correlations between the expected share of pipeline transport and other variables investigated in this survey are likely to seem random.

Overall, 19% of experts' responses were significantly inter-correlated. It needs to be emphasised that significant correlations between variables do not imply causality, though they can identify links and connections between experts' responses and shed light on their underlying reasoning. They also helped to identify which variables had the strongest correlations with the overall changes in the key logistics parameters and, thus, are more likely to be important factors to be considered when trying to influence the future trends in these parameters. Additionally, the correlation analysis confirmed that in the vast majority of cases identified, significant relationships between variables are logical. Thus, participants' responses are extremely unlikely to be random, confirming the validity of the survey findings.

6.3. Comparison of Delphi Results and Focus Group Findings

Overall, the results of the Delphi survey confirmed the findings from the focus group discussions. However, some divergent opinions on the future trends in the key logistics parameters and factors influencing these have also emerged. The similarities and differences between the main findings from both parts of the research project are summarised below.

The focus group participants' views on the possible changes in **average length of haul** and **handling factor** suggested that, although there may be some shifts within sectors, the UK-wide situation is going to remain relatively stable. This was confirmed by the Delphi panellists who indicated only marginal changes in the average distance travelled by HGVs and no further changes in handling factor by 2020. The participants in the focus group discussions were convinced that supply chain structures within the UK have reached their maximum level of centralisation and a reversal of this trend is now likely. They also predicted increasing importance of local sourcing, especially in the food sector. The Delphi study, on the other hand, suggested that on balance the centralisation of manufacturing and warehousing is likely to continue at least until 2020. The panellists also concluded that global sourcing of supplies will be much more important than any local sourcing strategies. The apparent contradiction in experts predictions about average length of haul, handling factor, centralisation pressures and wider sourcing can be explained by likely developments in hub & spoke networks, the development of urban consolidation centres and increased frequency of primary consolidation initiatives.

Positive changes in **empty running** and **lading factor** trends were foreseen by both focus group and Delphi survey participants. It emerged from the focus group discussions that companies are already quite successful in optimising utilisation of their fleets. However, further improvements were still expected by the survey panellists. At the focus group meetings, working time regulations, telematics systems and rising cost of transport were three main factors listed as having the greatest influence on the amount of empty running. Consolidation and collaboration initiatives, JIT practices and issues regarding packaging of products and pallet stacking were three main issues believed to affect lading factor. The same points were attributed high importance by the Delphi experts.

Regarding the **modal shift** issue, rail or waterborne transport were not considered viable logistics options for the majority of organisations represented at the focus groups. Further, a more positive attitude towards waterborne transport than towards rail was evident. A slightly different picture emerged from the Delphi survey. A modest positive change in modal shift was expected with rail likely to experience the greater gain of market share (2.4%), while the share of waterborne transport was expected to increase by only 1.5%. Also, although participants acknowledged that there are numerous obstacles that may affect the opportunities modal shift in the future, all in all the constraints on both rail and waterborne transport were expected to ease by 2020.

In connection with **fuel efficiency**, drivers' training, IT systems (including telematics) and high fuel prices were issues most frequently mentioned by focus group participants. Similarly, the Delphi panellists regarded them as important future fuel efficiency measures. However, according to the Delphi experts, vehicle design was the most important measure to improve the fuel efficiency of lorries. Although alterations to vehicle design were mentioned at focus group workshops, they were not amongst the most frequently listed measures. Carbon intensity of fuel was expected to decline in the future by participants in both parts of this research project.

As explained earlier, between the focus group and Delphi participants there was a high degree of consensus as to majority of issues investigated. This can be partly explained by the fact that one of the objectives of the focus group research was to identify issues for further investigation by the means of the Delphi survey. Thus, had the results been markedly different, doubt would have been cast on the reliability of these opinion surveys. Slight differences in opinion on some of the future trends may also be a result of different time scales used to elicit experts' projections. While the Delphi panellists had a specified time scale for constructing their forecasts (2020), the focus groups participants seemed to mix examples from their current experience with future predictions. Overall, it can be concluded that the Delphi survey confirmed and quantified the results of focus group discussions, which fulfils the underpinning assumptions of methodological triangulation adopted in this thesis.

6.4. Potential Limitations of the Research

The purpose of the Delphi survey was to produce a reliable forecast of BAU trends in a series of key logistics and road freight transport variables and likely future changes in a

number of factors determining these trends. As discussed earlier in the thesis, the Delphi method has been selected as it is likely to yield the most reliable results in a given research setting, i.e. for example long-term forecasting period, recent breaks in the statistical data series, size of the climate change challenge and lack of similar external pressures in the past. However, the Delphi method is a qualitative forecasting technique and as such relies strongly on expert human judgement rather than on hard, measureable and verifiable data. This reliance on expert judgement is a source of potential unreliability of results, due to two main reasons. Firstly, in the literature there is lack of formal criteria for judging who should be considered an expert, and, secondly, being an expert does not guarantee infallibility. The first problem was addressed by adopting formal selection criteria of at least five years of experience in logistics-related position to ensure participants have “sufficient knowledge and experience” to become members of the panel. As 83% of participants occupied senior positions within their organisations it is very likely that the vast majority had considerably more than five years of experience in the logistics-related jobs. Regarding the reliability of expert opinion a large panel has been employed to increase the accuracy of results. The data collected was screened for outliers to detect obvious mistakes (for example typing errors). Also, standard deviation and spread of responses were assessed at the data analysis stage in order to detect cases with significant divergence of opinion between panellists. These measures are believed to ensure maximum reliability of results obtained from the Delphi survey.

Also, long-term forecasting questions are inherently difficult to answer even for experts in the field, which may result in limited accuracy of Delphi results. Rapid science or technological breakthroughs may not be foreseen by the majority of main stream oriented experts (Blind, 2008). Further, even if a breakthrough future development is indicated by some of the panellists, the Delphi method is designed in a way that discourages more radical views and promotes convergence process (Bardecki, 1984, Stewart, 1987). This may result in ignoring important but unorthodox opinions and generating artificial consensus (Sackman, 1974). High risk of overlooking sudden, radical breakthrough events in the future applies to all long-term forecasting techniques. To minimise this risk, the data was carefully screened to identify atypical responses and differences in opinion, as described above. Also, the option “other, please specify” was given in the majority of the questions to enable respondents to point out any important issues that had been not listed in the questionnaire.

Another problem associated with Delphi surveys is potential lack of consensus in the returns. The standard deviation values in the first round of the Delphi survey revealed differences of opinion on some of the key variables. However, overall the Delphi process produced, on average, a 9% convergence of expert views (measured as an average reduction in standard deviation between rounds). Where statistically significant differences in opinion persisted between respondents in different stakeholder or industry groups, additional analysis was carried out to avoid misrepresenting their viewpoints.

Similarly as with focus group research, the panellists were informed that this survey was part of the Green Logistics project. This may have increased the risk of some experts wanting to influence the research findings to promote ideas beneficial for organisations or sectors they represent and thus bias the results. Employing a large number of individuals to take part in the panel, asking them to take a long term perspective of this project, sending the invitations from a Heriot-Watt University email account and emphasising the academic nature of this research in the attached information are believed to have minimised the risk of this occurring.

6.5. Conclusions

The aim of this Chapter was to present the logistics experts' perspective on the likely changes in the main factors determining the environmental performance of road freight transport, on a BAU basis. It has been shown that climate change and CO₂ emissions are clearly becoming significant factors in logistical decision-making. Over 50% of companies involved in road freight transport operations believe they will see their activities affected by climate change concerns to a significant or large extent by 2015. This is expected to rise to over 80% by 2020.

Some long-established production and logistics trends which exert a strong influence on road freight demand, such as the centralisation of manufacturing and inventory, the adoption of JIT replenishment and the outsourcing of non-core activities, cannot continue indefinitely. The results of the Delphi survey reported in this paper suggest that these trends are likely to continue at least until 2020. They also show the complexity of the inter-relationships between a broad range of business trends, freight traffic levels and related CO₂ emissions. While some of the trends predicted by the panel of experts will increase the environmental footprint of road freight operations, others will have the opposite effect. Generally speaking, many of the trends anticipated at the upper strategic, commercial and operational levels in the decision-making hierarchy are likely

to increase their environmental impact, while those projected to occur at a functional level in the management of transport resources will have an offsetting effect. However, if the BAU scenario is considered, overall changes in the key logistical variables, such as percentage of tonne-kms transported by road, average length of haul, empty running or lading factor, should have a positive or, in the worst case, neutral effect on the environmental performance of road freight transport. Improvements in vehicle utilisation are likely to be the source of the greatest ‘savings’ in CO₂ emissions from road freight transport, while no significant changes are expected to the supply chain structures. Future trends in handling factor and average length of haul are most likely to have only marginal effect on CO₂ emissions from lorries. A summary of changes in the key logistics variables projected by the Delphi panel is presented in Table 6.9 (compared to the 2007 level).

Variable	2007	2020	Absolute change	Relative change
Modal split				
Share of road	66%	59.8%	-6.2%	-9.4%
Share of rail	9%	11.4%	2.4%	+26.7%
Share of inland waterways	21%	24.5%	3.5%	+16.7%
Share of pipeline	4%	4.3%	0.3%	+7.5%
Supply chain structure				
Handling factor	3.4	3.4	0	0%
Average length of haul	86km	85.7 km	-0.3km	-0.3%
Vehicle utilisation				
Empty running	27%	21.9%	-5.1%	-18.9%
Lading factor	57%	64.4%	+7.4%	+13.0%
Fuel management				
Fuel efficiency (rigid / artic)	9.4/8.0 mpg	↗		
Carbon intensity of fuel (diesel)	2.63 (kg CO ₂ /litre)	↘		

Table 6.9. Projected changes in the key logistics variables

Comparing the 2007 data with baseline data used in the questionnaire, there has already been a marginal reduction in the average length of haul (1km) and vehicle utilisation factors have remained stable. Also, changes in some of the factors discussed in this Chapter are a result of internal business decisions, while others are imposed by other partners within a supply chain and other entities in the external economic and social environment, for example national and international governments, trade bodies or

consumer organisations. As a result, wider socio-economic business environment may have a crucial effect on the environmental performance of road freight transport and may limit options available to logistics operators to make their activities more sustainable. Hence, there needs to be more understanding and modelling of the impact of different policy interventions on the road freight transport in order to promote comprehensive sustainable solutions rather than the separate approaches to economic, environmental and social concerns. In the next Chapter, a spreadsheet-based forecasting model will be presented that could be used to simulate the effects of changes in key logistics parameters on CO₂ emissions from HGVs. First, a BAU scenario will be built based on the results of the Delphi survey and then a number of scenarios will be constructed and modelled to illustrate how different policy options are likely to alter the BAU case.

Chapter 7. Modelling CO₂ Emissions from Road Freight Transport

Aims of the chapter:

- *To quantify future CO₂ emissions on a BAU basis using the spreadsheet model constructed for the purpose of this research*
- *To construct and model a range of different scenarios to illustrate likely impacts of different policy options*
- *To show what changes in the key logistics variables would be required to meet the national carbon reduction target*

This Chapter is the last of three presenting empirical results of this research project. Based on the theoretical framework introduced in Chapter 3, a spreadsheet model has been developed that quantifies CO₂ emissions from road freight transport. Using the focus group and Delphi study research findings, a BAU scenario was modelled to estimate the reference-case levels of CO₂ emissions from HGVs in 2020. Further, alternative scenarios were derived, based on the original survey data as well as on other published sources, to assess the likely range of environmental impacts resulting from potential policy options. The modelling results are presented for the road freight transport sector as a whole as well as disaggregated by HGV classes.

In the second part of the Chapter, a backcasting approach is applied to estimate the scale of changes in the key logistics variables that would be required by 2020 for the industry to be on track to meet the UK target of reducing GHG emissions by at least 80% by 2050 (relative to their 1990 level).

As in Chapter 3, all statistics and estimates presented in this part of the thesis exclude Northern Ireland and unless stated otherwise, apply to Great Britain only. Also, when referred to ‘current’, the 2007 situation is assumed.

7.1. Measuring CO₂ Emissions from Road Freight Transport

As mentioned before, this thesis focuses solely on tailpipe/‘source’ CO₂ emissions. In this section different ways of measuring tailpipe CO₂ emissions on a macro-/national-scale will be presented. Choosing a particular approach is important as, depending on the definition of trucking activity, industry sector, the degree of reliance on survey, vehicle test-cycle and traffic count data and the geographical scope of the calculations, estimates can vary by as much as 30% for a single year (McKinnon and Piecyk, 2009).

McKinnon and Piecyk (2009) adopt four different approaches to estimate the total CO₂ emissions in GB (Figure 7.1):

1. CSRG¹⁵ - based estimation of CO₂ emissions from British-registered operators
2. Combination of traffic flow estimates of lorry-kms from NRTS¹⁶ with CSRG¹⁵-based fuel efficiency estimates
3. Combination of traffic flow estimates of lorry-kms from NRTS with fuel efficiency estimates based on vehicle test-cycle data
4. Estimate of total fuel sales to HGVs multiplied by the CO₂ conversion ratio.

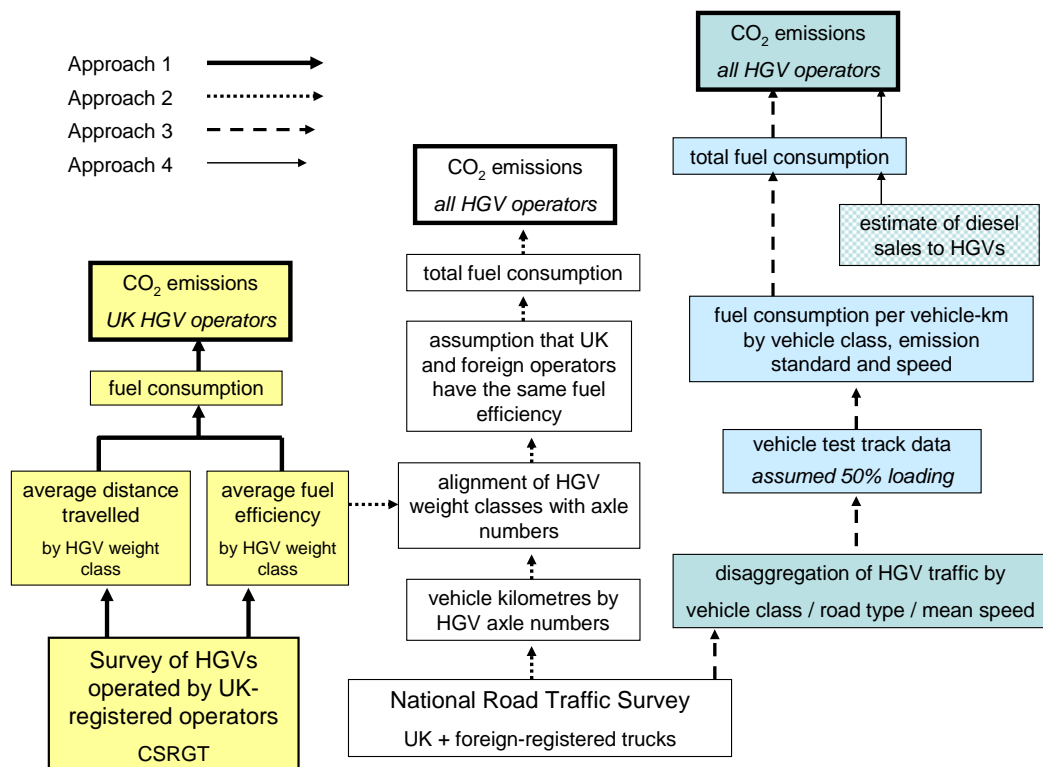


Figure 7.1. Four approaches to the calculation of territorial estimates of CO₂ emissions from HGVs
Source: McKinnon and Piecyk, 2009

Four estimates of CO₂ emissions from GB road freight transport are compared in Figure 7.2. The differences in results relate mainly to differences in methodology used and alignment of vehicle classifications. The first CSRG¹⁵-based approach to calculating CO₂ emissions from road freight transport in GB will be adopted in this thesis for a number of reasons.

¹⁵ Continuing Survey of Road Goods Transport

¹⁶ National Road Traffic Survey

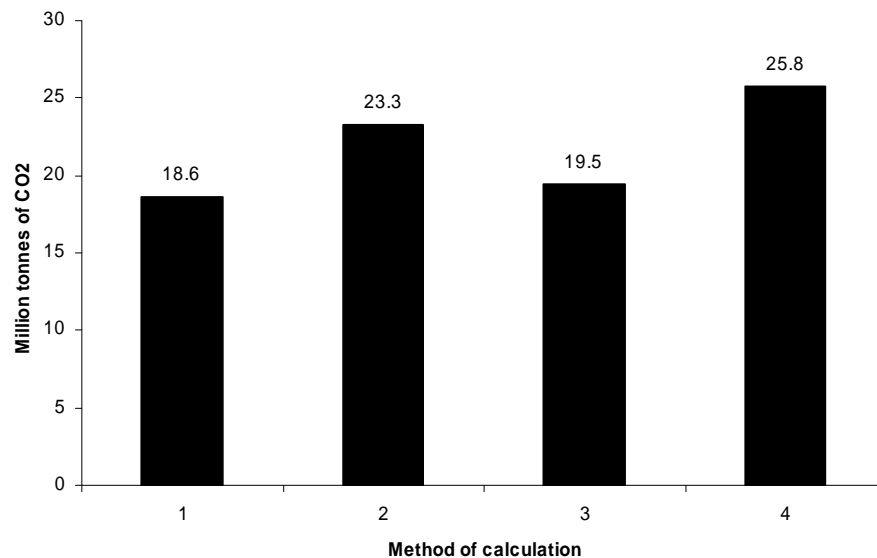


Figure 7.2. Estimates of total CO₂ emissions from GB road freight transport, 2006
Updated from: McKinnon and Piecyk, 2009

Firstly, approaches 3 and 4 rely on vehicle test-cycle data. In Approach 3 HGV traffic is first disaggregated by vehicle type, road type and average speed and then the emission factors derived from test-cycle data are applied to estimate the total CO₂ emitted by lorries in the GB. In Approach 4, the estimate of total fuel consumed by HGVs is derived by allocating these vehicles a share of total diesel fuel for road vehicles (DERV) on the basis of CSRG, NRTS and test-cycle data. Although the test-cycle fuel efficiency data is officially published by the UK Department for Transport, it can be argued that test-cycle conditions cannot exactly replicate on-the-road HGV operations, mainly because as McKinnon and Piecyk (2009) explain:

- Vehicle test cycle estimates are based on a limited sample and extrapolation is used to estimate values for other types, weights and vintages of vehicles.
- Although emission levels are monitored at different speeds, the variability of speeds across the range of traffic conditions experienced on a typical journey cannot be accurately simulated.
- Simplifying assumptions have to be made about the average loading of trucks. For most vehicle classes, the assumed 50% load factor over-estimates the actual level of vehicle utilisation.

Secondly, having just one macro-level figure for the total fuel sales (Approach 4) does not provide data for more disaggregated analysis.

Approaches 1 and 2 are based on the officially published CSRG T-based fuel efficiency estimates. This data source was considered as more reliable because it is based on a large sample of GB-registered vehicles operating in real on-the-road conditions. The main difference between Approaches 1 and 2 lies in the vehicle kms data source. Approach 1 relies on the CSRG T data, whereas the NRTS data is used in Approach 2. The NRTS data is derived from automatic and manual counts at various points on the national road network. This data is then combined with road lengths to produce overall vehicle km estimates (Department for Transport, 2009g). Although the NRTS could be an alternative source of total truck-km estimates for GB, it uses a different classification of vehicle categories and attempts to realign them with CSRG T vehicle classes pose a risk of potential inconsistencies in the results.

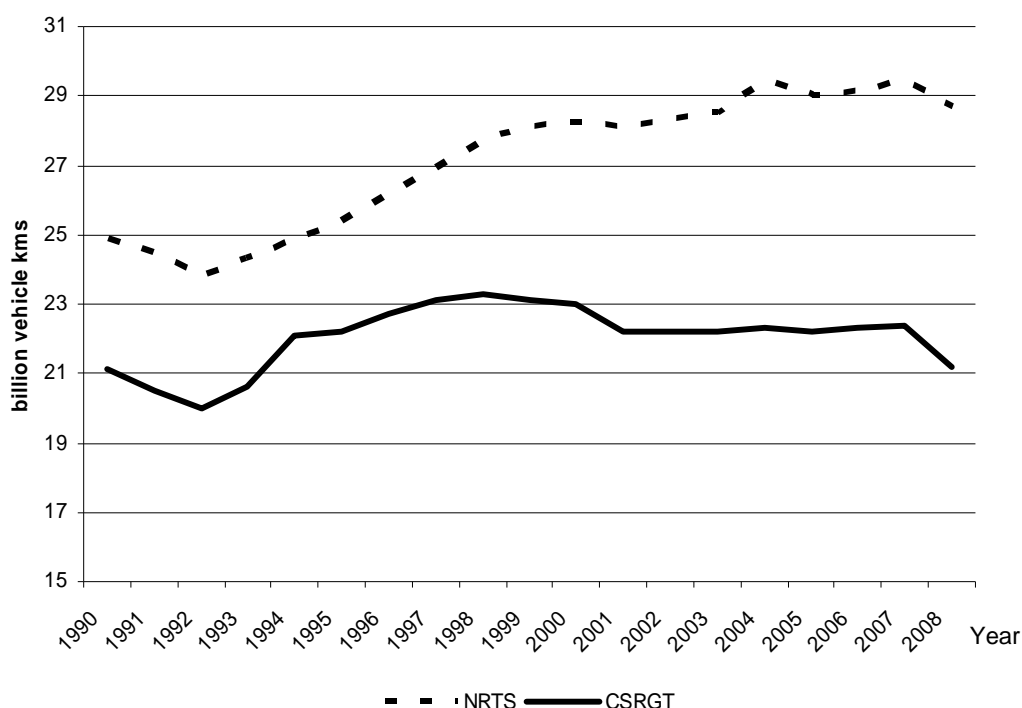


Figure 7.3. Vehicle kms – CSRG T and NRTS estimates
Source: Department for Transport, 2009a,g

Thirdly, over the years, the NRTS continuously yielded a higher estimate of HGV-kms than that derived from the CSRG T (Figure 7.3). In 2008, the difference in vehicle kms recorded by both surveys was 35%. This can be partly explained by exclusion of foreign-registered vehicles from the CSRG T. This thesis is focusing only on the GB-registered lorries, mostly due to uncertainty about the true extent of current foreign vehicle activity in GB (although a Foreign Vehicle Survey was conducted in 2009, only provisional, unweighted results were available at the time of writing) and lack of information on their operating characteristics (for example fuel efficiency, empty

running or average loading). Also, other reasons for the discrepancy between the NRTS and CSRGT estimates may also exist. Thus, for consistency reasons the CSRGT data is used throughout the thesis.

7.2. Model Development

A spreadsheet model has been constructed which simulates the relationship between freight traffic growth, a series of logistics variables and CO₂ emissions. As explained above, the freight data from the CSRGT was used to model HGV traffic in this thesis. The CO₂ conversion factors necessary to translate the freight-related variables into the environmental performance measures were taken from ‘Guidelines for Company Reporting on Greenhouse Gas Emissions’ published by DEFRA in 2005. These guidelines have been revised since the modelling work presented in this Chapter was completed (DEFRA, 2009). However, the conversion factor for diesel fuel increased by only 0.3% (from 2.63 to 2.6391 kg CO₂ per litre of fuel). Thus, the recent revision of the CO₂ conversion factor used in this thesis should not affect the accuracy of the results.

Spreadsheets have been used successfully in the past to model future vehicle exhaust emissions (e.g. Bailey, 1995, He et al., 2002). The flow chart of the model constructed for the purpose of this thesis is presented in Figure 7.4. The model is based on the theoretical framework introduced in Chapter 3. The ‘current’ situation is represented by the 2007 data. The modelling starts with the total tonne-km figure for all modes. Using the modal split variable, this is then converted to the amount of goods moved by road. Dividing road tonne-kms by the average length of haul yields a figure for road tonnes lifted. Laden vehicle kms are calculated using the total vehicle kms statistics and the empty running ratio. The average load for the GB HGV fleet can be then estimated by dividing road tonne-kms by laden vehicle kms. The average load is then used for two purposes. Firstly, to calculate the maximum load. The maximum load is assumed to remain unchanged in the future (i.e. current restrictions on gvw are not expected to be relaxed by 2020) and is then fed into the 2020 forecast. Indirectly, this also implies that the relative proportions of rigid HGVs and articulated HGVs remain at current levels. Secondly, the average load and road tonnes lifted values are used to estimate the total number of loads per year. This is then transformed to laden vehicle kms and total vehicle kms (through average length of haul and empty running figure, respectively).

The accuracy of the calculations can be then validated by comparing the calculated vehicle kms with the CSRGT estimate. Average fuel efficiency multiplied by the total vehicle kms gives the amount of fuel consumed across the British truck fleet. By applying the carbon intensity conversion ratio the total CO₂ emissions from road freight transport in the GB in 2007 are calculated. As can be seen in Figure 7.4, the ‘current’ version of the spreadsheet model is a disaggregated form of Approach 1 outlined in the previous section.

The following model variables can be altered to produce the 2020 forecast:

- Total tonne-kms
- Modal split
- Average length of haul
- Empty running
- Lading factor
- Fuel intensity
- Carbon intensity of fuel.

A disaggregated version of the model was also developed. It disaggregates the modelling process by six HGV classes. The vehicle categories used are consistent with the classification adapted by the CSRGT and include:

- Rigid vehicles over 3.5 tonnes to 7.5 tonnes
- Rigid vehicles over 7.5 tonnes to 17 tonnes
- Rigid vehicles over 17 tonnes to 25 tonnes
- Rigid vehicles over 25 tonnes
- Articulated vehicles over 3.5 tonnes to 33 tonnes
- Articulated vehicles over 33 tonnes.

7.3. Effects on the carbon footprint of road freight transport in 2020

In this section the modelling results are presented. First, the BAU case is discussed and then the likely impacts associated with alternative scenarios are outlined.

7.3.1. Business-as-usual (BAU) case

The BAU scenario was constructed on the basis of the mean responses of the Delphi panellists. The BAU case assumes the absence of any new policy interventions (e.g. road charging schemes, carbon taxes, relaxation of current restrictions on the size and weight of HGVs, etc), i.e. there will be no real change in external forces shaping the current course of logistics and road freight transport trends. As mentioned in the previous Chapter, the Delphi panellists were asked to assume the BAU scenario when responding to the survey questions.

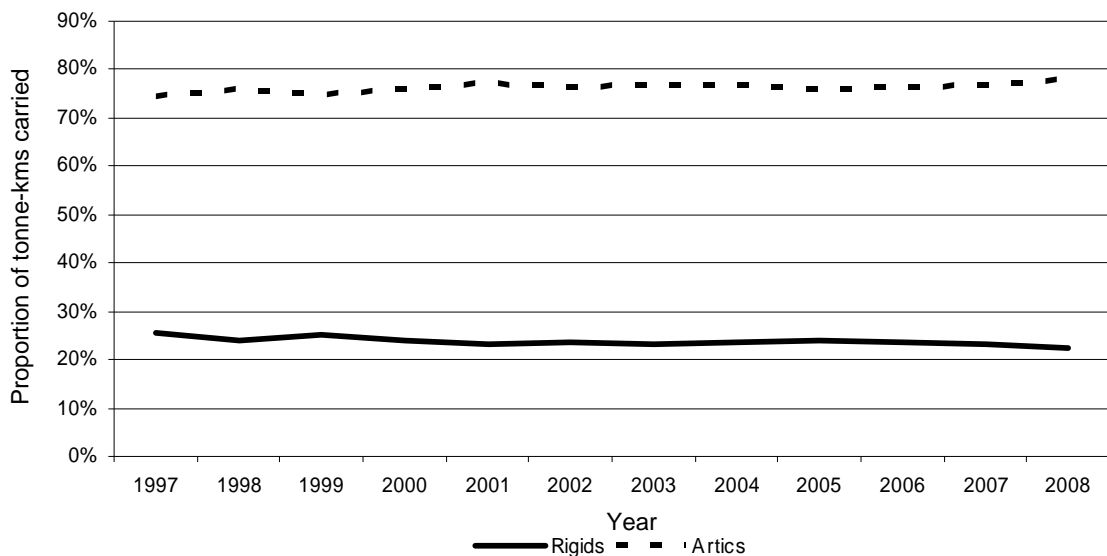


Figure 7.5. Shares of tonne-kms carried by rigid and articulated vehicles (1997-2008)

Source: Department for Transport, 2009a

The mean values for projected changes in tonne-kms, modal split, average length of haul, empty running and lading factor, were inserted into the model to show the combined effects of the changes in the key logistics parameters expected by the participants. Assumptions were made about changes in fuel efficiency (+5%) and the carbon intensity of fuel (-5%) as the survey did not attempt to quantify these directly. As discussed before, the results of focus group discussions indicated that experts felt confident to express their projections of the future course of the key logistics variables, but were less certain of the extent of potential future developments in fuel technologies. It was felt that technical knowledge beyond the current expertise of the majority of

participants is needed to make reliable projections of these fuel and carbon intensity variables. Thus, the survey questions were formulated to indicate the magnitude and directions of future changes rather than to ask about exact quantification of the extent of these changes. The BAU forecast assumes that the relative proportions of work carried out by rigid HGVs and articulated HGVs remain at current levels, as this has been stable over the last 10 years (Figure 7.5) and there are no projections available to indicate how this is likely to change in the future. The results of the analysis are shown in Table 7.1.

	Current (2007)	2020 BAU
Total tonne-kms (billion)	255	325
Share of road (HGVs)	63%	60%
Road tonne-kms (billion)	161	195
Lading factor	57%	64%
Empty running	27%	22%
Average length of haul (kms)	86	86
Tonnes lifted (billion tonnes)	1.9	2.3
Average load (tonnes)	9.8	11.1
Laden vehicle kilometres (billion)	16.4	17.5
Total vehicle kms (billion)	22.4	22.4
Projected change in fuel efficiency		+5%
Fuel efficiency (mpg)	8.7	9.1
Fuel efficiency (litre/km)	0.33	0.31
Projected change in carbon intensity of fuel		-5%
Conversion ratio (kg CO ₂ / litre of fuel)	2.63	2.50
Total fuel consumption (billion litres)	7.3	7.0
Total CO₂ emissions (million tonnes)	19.3	17.4
% change from current level		-10%

Table 7.1. Carbon footprint of road freight transport in Great Britain now and in 2020 (BAU scenario)

When the BAU scenario is considered, positive developments in modal split, vehicle utilisation, fuel efficiency and carbon intensity are likely to result in a 10% percent reduction in CO₂ emissions from the current level, decreasing the carbon footprint of road freight transport to 17.4 million tonnes of CO₂ in 2020. This occurs despite the fact that there would be an underlying growth in road tonne-kms of 21%. As the average length of haul is likely to remain relatively stable at around 86 kms, the increase in tonne-kms is driven mainly by a growth in the weight of goods transported (to 2.3 billion tonnes in 2020). Panellists predicted that the average number of links in the supply chain will also remain stable (handling factor of 3.4, see Chapter 6), suggesting that future increases in the transported weight will be due mainly to an increase in the physical mass of goods in the economy. The 21% increase in tonne-kms will be largely

offset by better loading (resulting in the weight of an average load rising to 11.1 tonnes from 9.8 tonnes) and less empty running of HGVs (5% reduction between 2007 and 2020). As a result, total truck-kms will not change. This is a very positive development when compared to the results from the Great Britain Freight Model (GBFM) which feeds into the Department for Transport's National Transport Model (NTM) and is then used to produce national road traffic forecasts (Department for Transport, 2008e). The GBFM projected a 0.7% growth in HGV kms per annum between 2004 and 2025 (MDS Transmodal, 2008). This would imply a 9.1% growth in truck kms between 2007 and 2020. The CO₂ implications of HGV- kms growth in line with the GBFM projections are presented later in this Chapter. When improvements in fuel efficiency and reductions in carbon intensity are factored into the calculation, total CO₂ emissions from road freight transport will actually fall by 2020. It is worth noting that the 5% improvement in fuel efficiency (on a litre/km basis) is assumed despite improvements in vehicle loading (i.e. heavier loads being carried). A study by Coyle (2007) suggests that fuel consumption deteriorates at an average rate of 0.112 mpg (0.316 litre/km) by tonne of increased payload, thus small changes in payload weight will have only a little effect on the overall fuel efficiency.

Table 7.2 shows the results disaggregated by HGV class, assuming that forecast changes in the key parameters are uniform across all vehicle classes and their shares of freight tonne-kms remain constant. Articulated vehicles would be responsible for 55% of the total truck-related CO₂ emissions but moving 77% of the total road tonne-kms. The fuel consumption across the whole articulated fleet would decline from 4 to 3.8 billion litres per year. The average load carried by the heaviest lorries (over 33 tonnes) would increase to 16.8 tonnes (from current 14.8 tonnes).

The rigid trucks between 7.5 and 17 tonnes would remain poorly utilised with only a 42% lading factor, whereas rigid vehicles over 25 tonnes are likely to have the highest empty running figure of 28% (well above the overall average of 22%) partly reflecting their very short average length of haul – only around 36 kms in 2020. Across the HGV fleet as a whole, the average length of haul would vary from 36 kms to around 124 kms for the heaviest articulated trucks. Overall, rigid HGVs would consume 3.2 litres of fuel in 2020, contributing 7.9 million tonnes of CO₂ (45% of the total).

	Current									2020 BAU								
	Rigid vehicles					Articulated vehicles			All vehicles	Rigid vehicles					Articulated vehicles			All vehicles
	Over 3.5t to 7.5t	Over 7.5t to 17t	Over 17t to 25t	Over 25t	All rigids	Over 3.5t to 33t	Over 33t	All artics		Over 3.5t to 7.5t	Over 7.5t to 17t	Over 17t to 25t	Over 25t	All rigids	Over 3.5t to 33t	Over 33t	All artics	
Change in the total tonne-kms	100									127								
Total tonne-kms	255									325								
Share of road	0.63									0.60								
Road tonne-kms	161									195								
% of road tonne-kms	2%	2%	6%	14%	23%	3%	73%	77%	100%	2%	2%	6%	14%	23%	3%	73%	77%	100%
tonne-kms by different vehicle types	3.1	2.6	9.5	22.4	37.6	5.6	117.8	123.4	161.0	3.8	3.2	11.5	27.1	45.5	6.8	142.5	149.2	194.8
Lading factor	0.4	0.37	0.45	0.64	0.53	0.43	0.6	0.59	0.57	0.45	0.42	0.51	0.72	0.60	0.49	0.68	0.67	0.64
Empty running	0.28	0.24	0.23	0.34	0.28	0.23	0.27	0.26	0.27	0.23	0.19	0.19	0.28	0.23	0.18	0.22	0.21	0.22
Laden running	0.72	0.76	0.77	0.66	0.72	0.77	0.73	0.74	0.73	0.77	0.81	0.81	0.72	0.77	0.82	0.78	0.79	0.78
Average length of haul	56	50	73	36	44	113	124	124	86	55.8	49.8	72.7	35.9	43.8	112.6	123.6	123.6	85.7
Tonnes lifted (billion)	0.06	0.05	0.13	0.62	0.86	0.05	0.95	0.99	1.87	0.07	0.06	0.16	0.76	1.04	0.06	1.15	1.21	2.27
Average load	1.2	2.7	4.4	10.3	4.7	7.3	15.6	14.8	9.85	1.3	3.0	5.0	11.7	5.4	8.2	17.6	16.8	11.1
Max load	3.0	7.2	9.8	16.2	8.9	16.9	26.0	25.1	17.3	3.0	7.2	9.8	16.2	8.9	16.9	26.0	25.1	17.3
No of loads (million)	47	20	29	60	181	7	61	67	190	51	21	32	65	194	7	65	72	204
Laden vehicle kms (billion)	2.6	1.0	2.1	2.2	7.9	0.8	7.5	8.3	16.4	2.8	1.1	2.3	2.3	8.5	0.8	8.1	8.9	17.5
Total vehicle kms (billion)	3.7	1.3	2.8	3.3	11.1	1	10.3	11.3	22.4	3.7	1.3	2.8	3.2	11.1	1.0	10.3	11.3	22.4
Change in fuel efficiency										0.05								
Change in conversion of fuel to CO ₂										-0.05								
Fuel consumption (litre/km)	0.21	0.28	0.30	0.42	0.30	0.32	0.36	0.35		0.20	0.26	0.28	0.40	0.29	0.30	0.34	0.34	
Total fuel consumption (billion litres)	0.8	0.4	0.8	1.4	3.3	0.3	3.7	4.0	7.3	0.7	0.3	0.8	1.3	3.2	0.3	3.5	3.8	6.96
Conversion ratio (kg CO ₂ /litre of diesel)	2.63									2.50								
Total CO ₂ emissions (million tonnes)	2.0	0.9	2.2	3.7	8.8	0.8	9.7	10.5	19.3	1.8	0.9	2.0	3.2	7.9	0.8	8.8	9.5	17.4

Table 7.2. Carbon footprint of road freight transport in Great Britain now and in 2020 by HGV class (BAU scenario)

7.3.2. *Optimistic and pessimistic scenarios*

After the BAU case was modelled, the optimistic and pessimistic scenarios were constructed. This was done to reflect the fact that, although a substantial degree of consensus was reached, the experts were not unanimous. Thus, constructing extra scenarios helps to reflect the differences in opinion. The optimistic and pessimistic scenarios were defined, respectively, as being one standard deviation above and below the mean value of each key parameter. The standard deviation is a statistic that shows how tightly all the various responses are clustered around the mean in a set of data. One standard deviation away from the mean in either direction accounts for around 68% of the responses in the group. Two standard deviations away from the mean account for roughly 95% of the responses, and three standard deviations account for about 99%. It was decided to use one standard deviation as this covers more than two-thirds of responses. This also means that extreme opinions are excluded from the modelling reducing the risk of the results being over-optimistic or over-pessimistic. It should be noted at this stage of the analysis that the extreme opinions are still valid data points. Completely unrealistic values which appeared to be erroneous were eliminated from the data set before the statistical analysis. The optimistic and pessimistic projections of CO₂ emissions in 2020 are presented in Table 7.3.

	Current (2007)	2020 Optimistic	2020 Pessimistic
Total tonne-kms (billion)	255	271	378
Share of road (HGVs)	63%	54%	66%
Road tonne-kms (billion)	161	147	248
Lading factor	57%	70%	59%
Empty running	27%	18%	26%
Average length of haul (kms)	86	71	101
Tonnes lifted (billion)	1.9	2.1	2.5
Average load (tonnes)	9.8	12.1	10.1
Laden vehicle kilometres (billion)	16.4	12.1	24.5
Total vehicle kms (billion)	22.4	14.7	33.2
Projected change in fuel efficiency		+10%	-5%
Fuel efficiency (mpg)	8.7	9.6	8.3
Fuel efficiency (litre/km)	0.33	0.29	0.34
Projected change in carbon intensity of fuel		-10%	no change
Conversion ratio (kg CO ₂ / litre of fuel)	2.63	2.37	2.63
Total fuel consumption (billion litres)	7.3	4.3	11.4
Total CO₂ emissions (million tonnes)	19.3	10.3	30.0
% change from current level		-47%	+56%

Table 7.3. Carbon footprint of road freight transport in Great Britain now and in 2020 (optimistic and pessimistic scenarios)

In the optimistic scenario CO₂ emissions from road freight would be 47% below the current level (10.3 million tonnes of CO₂ in 2020). The modest increase in the total tonne-kms (6%) and a 9% shift of freight away from road, resulting in almost a half of all freight being transported by alternative modes and shortening of the average length of haul by 15 kms to 71 kms, would lead to a decrease in road tonne-kms of 8% (to 147 billion kms in 2020). Further, significant improvements in vehicle utilisation parameters (lading factor of 70% and empty running of only 18% resulting in the average load weighting 12.1 tonnes), would further convert this decrease in tonne-kms into a 34% reduction in the total vehicle kms (14.7 billion in 2020). In this scenario, the fuel efficiency of HGVs is assumed to improve by 10% and the carbon intensity of fuel to fall by 10%, reinforcing the beneficial CO₂ trend.

In the pessimistic scenario, the carbon footprint of the road freight sector increases to 30 million tonnes of CO₂ in 2020 (56% above the present level). An underlying growth in total tonne-kms of 48% is supplemented by a slight increase in road's share of the freight market (from 63 to 66%). Very modest improvements in vehicle utilisation (1% reduction in empty running and 2% increase in lading factor) will fail to offset this growth in road tonne-kms, resulting in a 48% increase in the total vehicle kms travelled (33.2 billion kms in 2020). This scenario also assumes slight worsening of fuel efficiency (-5%) which could be a consequence, for instance, of increasing traffic congestion or a further tightening of regulatory controls on emissions of other pollutants (for example, the imposition of the Euro 6 emission standard in 2013 can carry up to 10% fuel penalty (European Commission, 2007a, Keenan, 2008)). No change in the carbon intensity of fuel is assumed in this scenario, i.e. diesel fuel is assumed to remain the sole fuel option in the road freight transport sector.

The optimistic and pessimistic scenarios were also modelled for different HGV classes (Table 7.4). In the optimistic case, the annual fuel consumption by all trucks decreases by 41% to 4.3 billion litres, with heaviest articulated vehicles using up over a half of this total and, thus, contributing 54% of the total HGV-related CO₂ emissions. Lading factor of 74% and empty running of 17% and shortening of the average length of haul to 83 from current 124 km would contribute to the improved performance of this category of vehicles. Better vehicle utilisation would also more than offset the 12% increase in tonnes lifted by the heaviest lorries, resulting in a 9% reduction of the average number of loads moved in 2020.

	2020 Optimistic									2020 pessimistic								
	Rigid vehicles					Articulated vehicles			All vehicles	Rigid vehicles					Articulated vehicles			All vehicles
	Over 3.5t to 7.5t	Over 7.5t to 17t	Over 17t to 25t	Over 25t	All rigids	Over 3.5t to 33t	Over 33t	All artics		Over 3.5t to 7.5t	Over 7.5t to 17t	Over 17t to 25t	Over 25t	All rigids	Over 3.5t to 33t	Over 33t	All artics	
Change in the total tonne-kms	106									148								
Total tonne-kms	271									378								
Share of road	0.54									0.66								
Road tonne-kms	147									248								
% of road tonne-kms	2%	2%	6%	14%	23%	3%	73%	77%	100%	2%	2%	6%	14%	23%	3%	73%	77%	100%
tonne-kms by different vehicle types	2.9	2.4	8.7	20.5	34.4	5.1	107.8	112.9	147	4.8	4.1	14.6	34.5	58.0	8.6	181.6	190.2	248
Lading factor	0.49	0.46	0.55	0.79	0.65	0.53	0.74	0.73	0.70	0.41	0.38	0.46	0.66	0.54	0.44	0.62	0.61	0.59
Empty running	0.19	0.16	0.15	0.22	0.19	0.15	0.17	0.17	0.18	0.28	0.23	0.23	0.33	0.28	0.22	0.26	0.26	0.26
Laden running	0.81	0.84	0.85	0.78	0.81	0.85	0.83	0.83	0.82	0.72	0.77	0.77	0.67	0.72	0.78	0.74	0.74	0.74
Average length of haul	46	41	60	30	36	93	102	102	71	66	59	85	42	52	132	145	145	101
Tonnes lifted (billion)	0.06	0.06	0.14	0.69	0.95	0.06	1.06	1.11	2.08	0.07	0.07	0.17	0.82	1.13	0.07	1.25	1.31	2.47
Average load	1.5	3.3	5.4	12.7	5.8	8.9	19.2	18.3	12.1	1.2	2.7	4.5	10.6	4.9	7.5	16.0	15.2	10.1
Max load	3.0	7.2	9.8	16.2	8.9	16.9	26.0	25.1	17.3	3.0	7.2	9.8	16.2	8.9	16.9	26.0	25.1	17.3
No of loads (million)	43	18	27	54	163	6	55	61	172	61	25	38	77	231	9	78	86	244
Laden vehicle kms (billion)	2.0	0.7	1.6	1.6	5.9	0.6	5.6	6.2	12.1	4.0	1.5	3.2	3.2	11.9	1.2	11.3	12.5	24.5
Total vehicle kms (billion)	2.4	0.9	1.9	2.1	7.2	0.7	6.8	7.5	14.7	5.5	1.9	4.2	4.9	16.5	1.5	15.3	16.8	33.2
Fuel efficiency	0.1									-0.05								
Conversion of fuel to CO2	-0.1									no change								
Fuel consumption (litre/km)	0.19	0.25	0.27	0.38	0.27	0.29	0.32	0.32		0.22	0.29	0.31	0.44	0.32	0.33	0.38	0.37	
Total fuel consumption (billion litres of diesel)	0.4	0.2	0.5	0.8	2.0	0.2	2.2	2.4	4.3	1.2	0.6	1.3	2.2	5.2	0.5	5.7	6.2	11.4
Conversion ratio (kg CO2/litre of diesel)	2.37									2.63								
Total CO2 emissions (million tonnes)	1.1	0.5	1.2	1.9	4.6	0.5	5.2	5.6	10.3	3.1	1.5	3.4	5.7	13.7	1.3	15.1	16.4	30.0

Table 7.4. Carbon footprint of road freight transport in Great Britain now and in 2020 by HGV class (optimistic and pessimistic scenarios)

As discussed above, realisation of the pessimistic scenario would raise the annual fuel consumption to 11.4 billion litres and result in 56% increase in CO₂ emissions. The lading factor would range from 38% for rigid vehicles in the 7.5 - 17 tonne category to a maximum of 66% for the rigids over 25 tonnes. Empty running would vary from 22% in the case of small articulated vehicles to 33% for the largest rigid trucks. For articulated lorries, the average length of haul would rise to as much as 145 km and the number of loads carried would go up by 28% (to 86 million loads per annum). The average load carried by the articulated trucks over 33 tonnes would increase marginally from 15.6 to 16 tonnes. Rigid vehicles would travel on average 52 km per trip carrying 231 million loads of average weight of 4.9 tonnes.

The optimistic and pessimistic scenarios represent extreme cases and should be used for illustrative purposes only. It is highly unlikely that all changes in the key logistics variables would go only in one, i.e. positive or negative, direction. It is possible that ‘worsening’ of one of the variables would induce a counteracting positive trend either directly or indirectly (i.e. by optimising other variables). For example, lengthening of the average length of haul is likely to intensify efforts to ensure optimum loading. Conversely, improvements in one aspect of logistics operation (e.g. improvements in fuel efficiency), may lead to so called rebound effect, where efficiency improvements result in the generation of more traffic as companies paradoxically increase transport use. Other examples of similar interdependencies are shown in Figure 7.6. However, it is possible that in the longer term, when climate change concerns become more important in the corporate decision making (in line with what the Delphi survey results indicate), there will be a major shift towards the optimistic scenario in all the variables .

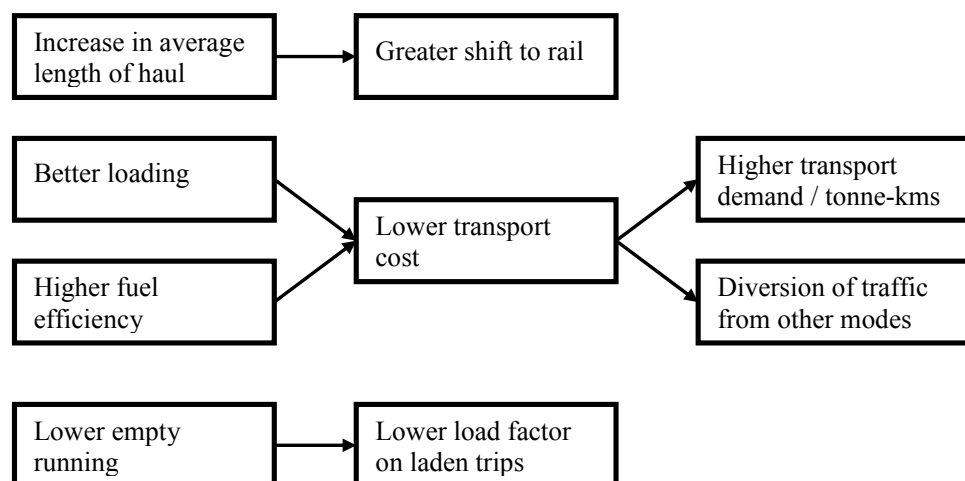


Figure 7.6. Possible interactions between key logistics variables

7.3.3. Projections based on other sources

The aim of this section is to show how the modelling results change depending on input variables. It compares the Delphi-based projections with other forecasts of the freight parameters a selection of published sources. No other published study has provided a comprehensive forecast of all variables considered in this thesis. However, different publications contain projections for one or more parameters, for example tonne-kms, vehicle kms or fuel efficiency. An attempt has been made to incorporate the projections derived from the literature into the relevant parts of the model and compare the results with the Delphi-derived scenarios. The vast majority of published forecasts are produced using traditional methods of forecasting (time series or econometric methods) and so they may present a different perspective on future trends in the key variables.

Alternative projections of tonne-km or vehicle kms growth

1. Mobility 2030: Meeting the Challenges to Sustainability

The Mobility 2030 report published by World Business Council for Sustainable Development (WBCSD, 2004) investigates how, on a global scale, sustainable mobility can be achieved and how progress towards this goal can be measured. In the reference projection, freight transport activity (measured in tonne-kms) is expected to growth at an average rate of 1.9% per year in OECD Europe between 2000 and 2030 (1.5% per year between 2000 and 2050). The tonne-kms carried by heavy duty trucks¹⁷ are expected to increase at an annual rate of 2.7% worldwide between 2000 and 2030 (2.4% between 2000 and 2030). This, however, is an average global figure and, as discussed in Chapter 6, may not be applicable to the UK. Thus, the overall rate of freight traffic growth in OECD Europe was used to estimate the freight tonne-kms in GB in 2020 (Table 7.5). These projections were then input into the model.

	% growth per annum	% growth 2007-2020	2007 (billion tonne- kms)	2020 (billion tonne-kms)
2000 - 2030	1.9%	24.7%	255	318
2000 - 2050	1.5%	19.5%	255	305

Table 7.5. Projected increase in vehicle kms (Mobility 2030 estimates)

It is worth noting here that the expected volume of freight in 2020, estimated using the 2000-2030 average annual growth rate, is very similar to the BAU Delphi projections

(318 and 325 billion tonne-kms respectively). When the 2000-2050 average annual growth rate is applied, the Mobility 2030 projections are 6% lower than the BAU case.

II. European Energy and Transport – Trends to 2030 (EET)

The European Energy and Transport – Trends to 2030 report published by (European Commission, 2003) and updated in 2007 (European Commission, 2008b) reviews likely economic, energy, transport and CO₂ trends for Europe. The difference between the 2003 and 2007 estimates is significant, with almost one-third divergence for the 2020 forecast (Table 7.6). Interestingly, the revised projections of truck tonne-kms in 2020 (195 billion) are precisely the same as those envisaged by the Delphi experts. This finding is quite remarkable, considering that the forecasting methods differed and there was no collusion between the two studies.

	2000	2005	2020	2030
Trucks (billion tonne-kms) 2003 projections	165.8	184.0	283.2	365.4
Trucks (billion tonne-kms) 2007 projections	165.6	167.5	195.0	205.9
Difference	-0.1%	-9%	-31%	-44%

Table 7.6. EET projections of truck tonne-kms in the UK
Source: European Commission, 2003, 2008b

The revisions of the country-level estimates are not discussed in the report. However, on the European scale, the updated baseline scenario “takes into account the high energy import price environment of recent years, sustained economic growth and new policies and measures implemented in the Member-States” (European Commission, 2008b, p.11). Similarly to the Mobility 2030 projections and the approach adapted in this thesis, the EC forecast is compiled on a BAU basis. As explained in the report, “the baseline scenario is a projection of the future evolution of the European energy demand and supply system reflecting business-as-usual trends, (...) i.e. it has been assumed that future changes are only influenced by policies and measures adopted in the past: no additional policies and measures are assumed for this scenario” (European Commission, 2008b, p.19). The initial (2003) estimates are still used in this thesis, primarily for illustrative purposes.

Both revised and original EET 2020 projections were input into the model in order to compare the projected CO₂ emissions resulting from both scenarios. Furthermore, based

¹⁷ The report defines heavy duty trucks as vehicles over 15 tonnes gvwt.

on the EET results, an average rate of growth was calculated (similarly to the Mobility 2030 approach) and combined with actual 2007 road tonne-kms figure (which is slightly lower than the 2005 figures in the report) to derive a 2020 estimate (Table 7.7).

	% growth per annum	% growth 2007-2020	2007 (road billion tonne-kms)	2020 (road billion tonne-kms)	Difference between EEA and calculated estimate
2000 – 2030 (2003 projections)	4%	52%	161	245	15.6%
2000 – 2030 (2007 projections)	0.8%	10.5%	161	178	9.5%

Table 7.7. Projected increase in vehicle kms (EET growth rate estimates)

It can be seen from Table 7.6, that before the 2007 revisions, truck tonne-kms forecast for 2020 were even higher than in the pessimistic scenario (283 and 248, respectively, a difference of 34 billion tonne-kms). However, when the calculated 2000 - 2030 average annual growth rate (before the 2007 revisions) is applied, truck tonne-km projections are almost identical to the pessimistic case (245 billion tonne-kms). When the revised annual rate of growth is used, the calculated road tonne-kms are slightly lower than the BAU projection (178 compared with 195 billion tonne-kms, a difference of 17 billion tonne-kms). The similarities between our projections and the estimates based on the EET report provide some corroboration of the findings presented in this thesis.

III. The Great Britain Freight Model (GBFM)

The model was also recalibrated using the output from the GBFM, i.e. the freight part of the NTM. The GBFM “uses trade, transport, and economic statistics to construct a detailed matrix of freight flows, and then uses supply side information (networks and transport costs) to assign the flows to multi-modal paths” (MDS Transmodal, p.2), i.e. the model transforms flows of goods into flows of vehicles. Thus, for HGVs the main output from the GBFM is a forecast of HGV kms split by vehicle type, road type, area type or region. According to the Department for Transport, the output from NTM/GBFM is a central forecast and assumes continuation of current policies up to 2025. Hence, in this scenario HGV kms are expected to grow in line with the GBFM projections (Table 7.8).

	GBFM forecast (% growth in vehicle kms, 2004-2025)	% growth per annum	% growth 2007-2020	2020 (billion kms)
Rigid vehicles	6.96%	0.32%	4.16%	11.6
Articulated vehicles	22.83%	1.04%	13.52%	12.8
All HGVs	15.81%	0.7%	9.1%	24.4

Table 7.8. Projected increase in vehicle kms (GBFM estimates)

As mentioned above, the GBFM does not estimate tonne-kms but produces a forecast of vehicle kms. The GBFM estimates are slightly higher than those in our BAU scenario (24.4 and 22.4 billion vehicle kms, respectively)

IV. Comparison of Modelling Results

Estimated CO₂ emissions, modelled for different input variables, are presented in Table 7.9.

CO₂ emissions in 2020 (million tonnes) / % change from current level (19.3 million tonnes)		Other logistics variables at current levels (a)	Other logistics variables at levels projected by Delphi panellists (b)
Scenario 1	Freight tonne-kms – Mobility 2030 projections (2000-2030 average growth rate)	22.8 / 18%	17.0 / -12%
Scenario 2	Freight tonne-kms – Mobility 2030 projections (2000-2050 average growth rate)	23.0 / 19%	16.3 / -16%
Scenario 3	Road tonne-kms – EET projections (revised estimate)	22.2 / 15%	17.4 / -10%
Scenario 4	Road tonne-kms – EET projections (original estimate)	33.9 / 76%	25.3 / 31%
Scenario 5	Road tonne-kms – EET projections (2000-2030 average growth rate - revised estimate)	20.3 / 5%	15.9 / -18%
Scenario 6	Road tonne-kms – EET projections (2000-2030 average growth rate - original estimate)	29.4 / 52%	21.9 / 13%
Scenario 7	Vehicle kms – GBFM projections	21.1 / 9%	19.0 / -2%

Table 7.9. Projections of carbon footprint of road freight transport in Great Britain in 2020

There are no long-term projections of some freight parameters such as average length of haul, lading factor, empty running available in the literature. These parameters were quantified in the comparative modelling exercise in one of two ways. It was that either:

- The share of road freight transport, average length of haul, empty running, lading factor, fuel efficiency and carbon content of fuel will remain at the current (i.e. 2007) levels, or

- That changes in these parameters vary in line with the Delphi projections.

When all the key logistics variables are expected to remain at the 2007 levels (Table 7.9, column a), the CO₂ emissions from road freight transport are expected to rise by between 5% (Scenario 5a) and 76% (Scenario 4a). This is because all scenarios assume some growth in freight transport activity (measured in either tonne-kms or HGV kms) compared to the current levels. However, they assume that no change will occur in other logistics variables (e.g. modal split or empty running), which could potentially offset this increase.

If the aforementioned logistics variables were to change in line with the Delphi panellists' expectations, five out of seven scenarios would yield some savings in road freight related CO₂ emissions by 2020. This would vary from 2% (Scenario 7b) to 18% (Scenario 5b). However, the two scenarios where CO₂ emissions are still expected to increase (4b and 6b) are based on the initial EET projections that were afterwards revised downwards. The same comment applies to Scenarios 4a and 6b, which project 76% and 52% increases in CO₂ emissions when current levels in other variables are assumed. These scenarios were included in order to illustrate the magnitude of the CO₂ emission increases that would occur if the initial forecasts were to materialise.

Out of the five scenarios in which changes in the key logistics parameters expected by the Delphi panellists would be more than sufficient to offset the growth in the amount of freight traffic, three project CO₂ savings greater than the BAU case (Scenarios 1b, 2b and 5b). Scenario 3b, similarly to the BAU one, results in 10% savings. This is because, as noted above the road tonne-kms projected in the EET report are precisely in line with the Delphi experts' forecast. Only the GBFM-based option yields marginal savings of 2%, well below the BAU projections. These modelling results prove that the expected changes in modal split, supply chain structure, vehicle utilisation and fuel management would more than offset the future freight traffic growth at the rates projected in several published studies, still resulting in a net reduction of the road freight-related CO₂ emissions in 2020. As the Delphi projections represent the BAU scenario, this positive trend could be further reinforced by future policies / interventions.

Alternative projections of changes in fuel efficiency and/or carbon intensity of fuel

I. The National Transport Model (NTM)

As explained in the Carbon Pathways Analysis report (Department for Transport, 2008b), three scenarios were created in the NTM to model CO₂ emissions from transport sector in England. In the case of HGVs, fuel economy is assumed to improve by 16% by 2050 (i.e. by 0.8% per annum) in the central scenario. This fuel economy improvement rate is then decreased / increased by 50% to create low / high efficiency scenarios, respectively. Assuming changes in line with the NTM fuel economy improvement rates, between 2007 and 2020 the fuel efficiency rate would change by 5.2%, 10.4% or 20.8% in the low efficiency, central and high efficiency scenarios. Projected fuel consumption for different categories of HGV in 2020 in line with the three scenarios is shown in Table 7.10.

Fuel consumption (litre/km)	Rigid vehicles					Articulated vehicles		
	Over 3.5t to 7.5t	Over 7.5t to 17t	Over 17t to 25t	Over 25t	All rigids	Over 3.5t to 33t	Over 33t	All artics
5.20%	0.20	0.26	0.28	0.40	0.28	0.30	0.34	0.33
10.40%	0.18	0.25	0.27	0.38	0.27	0.28	0.32	0.32
20.80%	0.16	0.22	0.24	0.33	0.24	0.25	0.28	0.28

Table 7.10. Fuel efficiency for different vehicle classes in 2020 based on the NTM scenarios

II. TREMOVE

TREMOVE is a transport and emission model developed for the European Commission. The model covers passenger and freight transport in 31 countries and estimates transport demand, modal split, vehicle stocks and environmental impacts under different policy options. The model covers the period between 1995 and 2030 (TREMOVE, 2007a).

Based on the baseline predictions for the UK (TREMOVE, 2007b), an average annual fuel efficiency improvement rate for the period 2000 - 2020 was calculated (0.4% per year). Based on this estimate, a 4.7% increase in fuel efficiency would be expected between 2007 and 2020. This is in line with the 5% estimate assumed in the BAU scenario. The resulting fuel efficiency figures disaggregated by vehicle class are shown in Table 7.11. No changes in the carbon intensity of diesel fuel were factored into the TREMOVE model.

Fuel consumption (litre/km)	Rigid vehicles					Articulated vehicles		
	Over 3.5t to 7.5t	Over 7.5t to 17t	Over 17t to 25t	Over 25t	All rigids	Over 3.5t to 33t	Over 33t	All artics
4.7%	0.20	0.26	0.28	0.40	0.29	0.30	0.34	0.34

Table 7.11. Fuel efficiency for different vehicle classes in 2020 based on the TREMOVE estimates

III. Review of Low Carbon Technologies (LCT) for HGVs

This study conducted by RICARDO (2009) for the Department for Transport reviewed a number of technologies in order to identify those which offer the greatest potential to improve fuel efficiency or reduce carbon intensity of fuel, thus reduce the CO₂ emissions. These include:

- Aerodynamic trailers – up to 10% reduction in fuel consumption.
- Electric vehicle bodies (i.e. electrification of refrigeration and refuse bodies) – 10% - 20% reduction, depending on body type.
- Low rolling resistance tyres – average 5% reduction.
- Automated manual transmissions – up to 7% - 10% reduction.
- Electric vehicles – 100% potential tailpipe CO₂ reduction.
- Hybrids – up to 30% reduction in fuel consumption.
- CNG – 10% - 15% reduction in CO₂ emissions.
- Biodiesel – 5% - 90% on a life-cycle basis, depending on biodiesel type

The study, however, it does not provide the expected overall change rate in fuel economy. Given the uncertainty about implementation rates and the extent to which fuel / CO₂ savings will be cumulative, it is difficult to estimate the overall scale of potential future reductions in fuel consumption or the carbon intensity of fuel based on the findings of the report. Thus, assumptions have had to be made here. Fuel efficiency is assumed to increase by 15% (Table 7.12) and carbon intensity to decline by 20% / 30%. This would result in 2.10 / 1.84 kg CO₂ being emitted from burning a litre of diesel fuel in 2020.

Fuel consumption (litre/km)	Rigid vehicles					Articulated vehicles		
	Over 3.5t to 7.5t	Over 7.5t to 17t	Over 17t to 25t	Over 25t	All rigids	Over 3.5t to 33t	Over 33t	All artics
15%	0.18	0.23	0.25	0.36	0.26	0.27	0.30	0.30

Table 7.12. Fuel efficiency for different vehicle classes in 2020 based on assumptions related to the report by RICARDO

IV. The Renewable Transport Fuel Obligation (RTFO)

The RTFO was approved in October 2007. The RTFO legislation requires fuel suppliers to ensure a proportion of biofuel in diesel or petrol. After revisions in April 2009, the targets for biofuel content in road fuels are: 3.25% in 2009/10, 3.5% in 2010/11, 4% in 2010/12, 4.5% in 2012/13 and 5% for each subsequent obligation period. The target is likely to be subject to further increases to ensure the EU target set by the renewable Energy Directive (10% of energy used in transport to be renewable by 2020) is met. Thus, a 5 and 10% reduction in the carbon intensity of diesel is assumed. This is also consistent with our BAU and optimistic scenario. It needs to be emphasised that substituting 5 or 10% of the fossil fuel volume with biofuel will not result in direct 5 or 10% reduction of carbon intensity. As discussed in Chapter 3, as a result of lower heat value, substituting biodiesel for conventional diesel fuel may even lead to a 10% increase in the tailpipe CO₂ emissions. The reduction in carbon intensity associated with biodiesel is only possible on a life-cycle basis. This is a result of the sequestration effect i.e. absorption of CO₂ from the atmosphere as the plants to produce biodiesel grow (the difference between tailpipe, end user and life-cycle emissions is explained in detail in Chapter 2). Although this thesis focuses on the tailpipe emissions, for the purpose of this section it will be assumed that the biofuel added generates, on balance, zero CO₂ emissions.

V. Comparison of Modelling Results

Table 7.13. presents changes in CO₂ emission estimates based on different assumptions about fuel efficiency and carbon intensity derived from the aforementioned studies. As fuel efficiency is measured on the litre/km basis, there is no difference if other logistics variables remain at the current or Delphi-derived level because the BAU scenario projects no change in vehicle kms. It is also worth noting that there are no projections of worsening fuel efficiency in the literature. While it is recognised that there are factors that may lead to increased fuel consumption / CO₂ emissions (e.g. introduction of tightening emission controls of other pollutants, i.e. Euro 6 standard is estimated to increase fuel consumption by up to 10% (European Commission, 2007a, Keenan, 2008), it is assumed to be more than offset by other factors leading to an overall improvement in fuel efficiency of HGVs.

		CO₂ emissions in 2020 (million tonnes)
Scenario 1	Fuel efficiency – NTM low efficiency projections (5.2% improvement)	18.3
Scenario 2	Fuel efficiency – NTM central projections (10.4% improvement)	17.3
Scenario 3	Fuel efficiency – NTM high efficiency projections (20.8% improvement)	15.3
Scenario 4	Fuel efficiency – TREMOVE projections (4.7% improvement)	18.4
Scenario 5	Fuel efficiency – RICARDO projections (15% improvement, no change in carbon intensity)	16.4
Scenario 6	Carbon intensity – RICARDO projections (20% reduction, no change in fuel efficiency)	15.4
Scenario 7	Carbon intensity – RICARDO projections (30% reduction, no change in fuel efficiency)	13.5
Scenario 8	Combined RICARDO projections (15% increase in fuel efficiency, 20% reduction in carbon intensity)	13.1
Scenario 9	Combined RICARDO projections (15% increase in fuel efficiency, 30% reduction in carbon intensity)	11.5
Scenario 10	Carbon intensity – RFTO projections (5% reduction, no change in fuel efficiency)	18.3
Scenario 11	Carbon intensity – RFTO projections (10% reduction, no change in fuel efficiency)	17.4

Table 7.13. Projections of carbon footprint of road freight transport in Great Britain in 2020

As a result of these fuel efficiency improvements and/or reductions in carbon intensity, the CO₂ emissions would decrease by 1.0 to 7.8 million tonnes from the 2007 levels. Further, seven of the scenarios modelled (2, 3, 5, 6, 7, 8 and 9) offer savings greater than our BAU case. This illustrates the scale of potential environmental benefits if the projected changes were achieved.

This section has examined different projections of tonne-kms, vehicle-kms, fuel efficiency and carbon intensity of fuel. The changes in a range of key freight variables necessary to achieve the UK GHG reduction target are explored in the next section.

7.4. Meeting the UK GHG Emissions Reduction Target

The UK is currently the only country in the world that has a legally binding framework to respond to the climate change challenge. The Climate Change Act, introduced in 2008, requires UK GHG emissions to be reduced to at least 80% below 1990 levels by 2050. The interim target for 2020 requires an emission reduction of at least 34% relative to 1990 levels (21% relative to 2005) (Committee on Climate Change, 2009). It needs to be emphasised that the targets have been set for the UK economy as a whole and may

not be applied uniformly across all sectors, i.e. some sectors may be required to cut their emissions above the legal target, while in others reaching the 80% target will not be possible. The Low Carbon Transport – A Greener Future strategy document published by (Department for Transport, 2009c) recognises that due to the nature of the road freight transport, achieving the reductions in this sector in line with the overall UK GHG emission reduction target will be very challenging. It also states that switching to low carbon technologies and focusing on measures to improve fuel efficiency will be vitally important in improving the environmental performance of the road freight sector. The contribution of logistics to ensuring the long-term sustainability of the UK transport system is discussed in detail in the Delivering the Sustainable Transport System: The Logistics Perspective report (Department for Transport, 2008a).

Nonetheless, in this section an assumption is made that a 21% cut in CO₂ emissions in line with the GHG national targets (relative to the 2005) levels would be required by 2020. Using Approach 1 (see Section 7.1), CO₂ emissions from road freight transport were estimated at 18.4 million tonnes in 2005. If a 21% reduction is required, this sets a target of cutting HGV-related emissions to 14.5 million tonnes in 2020. It is worth noting that, when the optimistic scenario is considered, this target is easily exceeded by 4.2 million tonnes of CO₂. As discussed above, however, the optimistic scenario represents ‘the best case’, i.e. assumes positive changes in all the variables simultaneously. Thus, it is quite unlikely to materialise. Also, three of the scenarios, based on the results of other published studies which assume large improvements in fuel efficiency / carbon intensity of fuel, (Table 7.13) exceed the savings required. On the other hand, the most likely BAU scenario falls 2.9 million tonnes of CO₂ short of meeting the target. Hence, the aim here is to construct a number of scenarios to illustrate the possible combinations of changes in the key logistics variables capable of meeting the 14.5 million tonnes of CO₂ target for 2020.

First, the changes that would be required in each individual variable were modelled. This assumes that only this one parameter would vary and all the others would remain at their 2007 value:

- Reduction of the total freight tonne-kms to 192 billion tonnes. This translates to 121 billion tonnes moved by HGVs.
- Reduction of road’s share to 47.5% of the freight traffic market.
- Increase vehicle loading from 57% to 75.5% (in terms of weight) on laden trips.

- Reducing empty running from 27% to 3%.
- Reducing average length of haul from 86 kms to 65 kms.
- 25% improvement in fuel efficiency.
- 25% reduction in carbon intensity of fuel.

Modelling individual variables in this way shows that the desired change cannot be achieved by focusing policy measures on a single road freight parameter (such as for example promoting modal split or fuel efficiency initiatives).

The sample scenarios capable of meeting the 2020 target are presented in Table 7.14. Scenarios A to D assume the freight tonne-kms stay at 2007 level. Scenarios E to F assume future growth in tonne-kms in line with the BAU case. Tonne-kms in options I to L and M to P reflect respectively the optimistic and pessimistic scenarios. Finally, projections of freight tonne-kms in options R to U are based on the Mobility 2030 report (i.e. average annual growth rate between 2000 and 2050). Naturally, the scenarios requiring the least change to achieve the 2020 target are these assuming no or minimum growth in the amount of freight moved (A-D and I-L). None of the scenarios assumes any changes in the maximum permissible weight of vehicles. For the purpose of the modelling, parameters such as share of road, lading factor, empty running and average length of haul were varied within or very close to limits denoted by the optimistic and pessimistic scenarios. A wider range of possible improvement was allowed in the case of fuel efficiency and carbon intensity of fuel. Although a more conservative approach was adopted previously in the modelling of the BAU, optimistic and pessimistic trends in these variables (mainly due to the uncertainty of survey respondents), it is recognised that progress is being made and future improvements in fuel efficiency and carbon intensity well in excess of 10% are possible by 2020. Further, improvements of this magnitude are necessary if the 2020 target is to be achieved, as it will be extremely difficult to alter the other parameters sufficiently to meet the required level of savings. Thus, an allowance was made for up to 30% reduction in carbon intensity of fuel and 15% increase in fuel efficiency.

In all the scenarios the required savings are achieved by striking a balance between vehicle utilisation, average distance travelled, fuel efficiency and carbon intensity of fuel. Where a large increase in freight tonne-kms is projected, radical improvements in vehicle utilisation (lading factor around 68-71% and empty running of 18-22%), fuel

efficiency (10-15% increase) and carbon intensity (up to 30%) are required to meet the 14.5 million tonnes of CO₂ target. This is further reinforced by changes in modal split (road's share down up to 54%) and average length of haul (reduction to 76 kms). Where only modest or no growth in the freight transport volumes was assumed, the required changes were less dramatic but still significant (e.g. lading factor increasing to at least 60% in all cases).

A number of negative scenarios (e.g. G, K, R) were also constructed to examine what would happen if some variables followed an adverse trend over the next decade. This was done in an attempt to show what compensating adjustments would be necessary in other parameters. For example in Scenario K, an increase in the share of HGVs to 69% of the freight transport market and lengthening of the average length of haul to 100 kms, was offset by significant improvements in vehicle utilisation (lading factor of 70% and empty running of 21%) and fuel management (11% increase in fuel efficiency and 17% reduction in carbon intensity). Only a modest growth in the overall amount of freight traffic assumed in this scenario made this trade-off still feasible.

Combinations other than those presented in this section are also possible. The primary objective of this exercise was to present the magnitude of changes required and the nature of the trade-offs between the variables. In interpreting the results the following issues should also be given attention. The road freight transport sector's ability to cut its CO₂ emissions is very much dependent on the amount of goods moved within the economy. Demand for freight transport is created across a whole range of industries and is thus extraneous. The policies aiming to cut road freight related CO₂ emissions should, therefore, not only focus on the freight transport sector itself but also consider the wider socio-economic context (e.g. promoting sustainable consumption amongst ultimate consumers may have a disproportionately greater effect on the sector's CO₂ emissions than attempts to reduce empty running).

Scenarios meeting the 2020 target (14.5 million tonnes of CO₂)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	R	S	T	U
Total tonne-kms (billion)	255	255	255	255	325	325	325	325	271	271	271	271	378	378	378	378	305	305	305	305
Share of road	66%	54%	63%	60%	54%	60%	58%	66%	62%	60%	69%	56%	65%	63%	54%	60%	68%	57%	63%	60%
Road tonne-kms (billion)	168	138	161	153	176	195	189	215	168	163	187	152	246	238	204	227	207	174	192	183
Lading factor	64%	61%	69%	60%	70%	65%	70%	66%	65%	68%	70%	60%	70%	71%	60%	64%	60%	70%	69%	68%
Empty running	22%	26%	22%	25%	22%	23%	18%	22%	24%	23%	21%	25%	18%	19%	26%	23%	25%	21%	25%	28%
Average length of haul (kms)	86	86	100	86	86	80	100	90	86	90	100	76	86	100	86	80	86	86	100	78
Improvement in fuel efficiency	10%	5%	14%	10%	5%	10%	10%	14%	10%	10%	11%	3%	15%	15%	10%	15%	10%	8%	15%	10%
Reduction in carbon intensity of fuel	5%	-	3%	5%	5%	10%	15%	23%	5%	-	17%	-	20%	29%	30%	20%	30%	-	20%	5%

Table 7.14. Example combinations meeting the 2020 target

Also, attempts to reduce the carbon footprint of road transport may result in an increase in CO₂ emissions elsewhere (e.g. transferring more freight to alternative modes will increase emissions from these modes). These trade-offs need to be taken into account when the freight sector as a whole has to meet the CO₂ target. Further, if minimal or even no freight transport growth was to occur, this is likely to be a result of off-shoring of manufacturing activity and associated raw material, components and assemblies flows to lower labour cost countries (as discussed in Chapter 3). This definitely contributes to meeting the national GHG reduction target in the UK, but the CO₂ emissions are merely displaced to other parts of the world, leading to no net reductions or even an increase at a global scale. However, although vital, these considerations are beyond the scope of this thesis.

The next section examines the potential policy initiatives that will be required to promote the changes in key freight and logistics parameters that will be necessary to meet the CO₂ reduction targets for road freight transport.

7.5. Policies for Long-Term Reduction of CO₂ Emissions from Road Freight Transport

As shown in this Chapter, the BAU scenario does not offer sufficient savings in the road freight transport-related emissions to meet the UK long-term GHG emission reduction target. This suggests that pressures within business will not be strong enough to reduce the sector's impact to the desired extent and some further reinforcement will be required to achieve the necessary improvements in environmental performance. The key logistics variables can be modified by a range of public policy measures. In this section potential policy measures are discussed in the context of the modelling results and Delphi survey findings.

A wide range of existing policy measures which aim to reduce CO₂ emissions from transport is already in place. However, most of them focus on passenger cars as these constitute the main source of emissions from transport activities (e.g. OECD, 2002 or International Transport Forum, 2008). Policy measures focusing specifically on freight transport tend to be discussed in the context of urban distribution. For example, a recent study by Zanni and Bristow (2010), reviews a number of policies and assesses their likely impact on long-term CO₂ emissions from road freight transport in London. The

urban perspective adopted in this type of study limits the opportunity to extrapolate the findings to the freight transport sector at large.

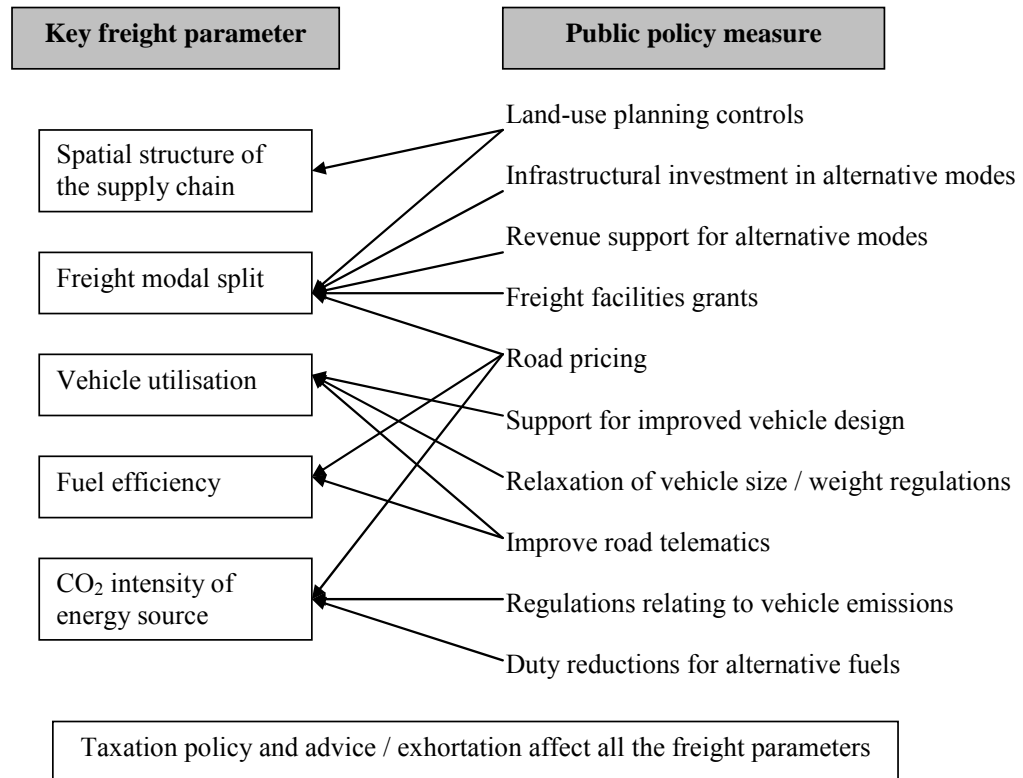


Figure 7.7. Impact of policy measures on the key logistics variables
Adapted from: McKinnon, 2008

The policy measures promoting CO₂ reductions from freight transport sector on a wider scale are discussed by McKinnon (2008) and International Energy Agency (2009). McKinnon (2008) divides the potential measures in to two broad categories: general measures such as taxation, emission trading or advisory programmes that can influence all of the key logistics parameters; the second category includes measures that are targeted at particular variables. The relationships between measures and variables are shown in Figure 7.7.

The comparison of the policy measures listed by McKinnon with the Delphi survey and modelling results yields several interesting points. The Delphi experts predicted an increase in primary consolidation of inbound loads and significant development of urban consolidation centres. Thus, promotion and operation of such facilities should be considered in local planning policies as an effective measure of cutting CO₂ emissions from HGVs, potentially very popular with companies operating in a given area.

When measures to promote shifting freight away from road to less energy intensive modes are considered, all options listed by McKinnon (2008) were assessed as effective by the survey participants. The measures designed to make the use of alternative modes easier and more reliable (e.g. upgrading rail or port infrastructure or provision of dedicated rail freight routes) were generally considered to be more effective than measures penalising the use of road (e.g. road pricing or more rigorous enforcement of regulations on road freight operators). Thus, the focus on the former initiatives may be more beneficial if major changes in modal split are sought. Recent reports by Rail Freight Group / Rail Freight Operators' Association and Rail Safety and Standards Board provide further support for this suggestion. They both stress the importance of investment in the rail infrastructure if this freight transport mode is to grow in the future (RSSB, 2007, RFG / RFOA, 2009).

The potential effectiveness of relaxing the current legal limits on vehicle size and weight was not explored in the Delphi survey nor factored into the spreadsheet model. A study on the potential effects of Longer and Heavier Vehicles (LHVs) recently commissioned by the Department for Transport has shown that allowing some vehicle combinations would help to limit the CO₂ emissions from road freight transport (TRL, 2008). However, the UK government decided not to permit any of the LHV scenarios evaluated in this study. Currently, a follow-up study is investigating the case for legalising one of the scenarios – a longer semi-trailer. It looks into the possibility of trailers up to 2.05m longer than the existing 13.5m standard. However, major changes in restrictions on vehicle weight size and weight do not seem realistic, at least within the next few years. Supporting innovative vehicle design within existing weight and size limits can still bring some benefits in terms of improved utilisation and environmental performance.

Support for improved IT solutions (e.g. telematics) offers great potential to contribute to a reduction of emissions from trucks, especially as such software was judged by the experts as the second most important measure of improving fuel efficiency.

Regulations relating to vehicle emissions and duty reductions for alternative fuels were not considered in the questionnaire but were factored indirectly into the model through scenarios with higher fuel efficiency and lower carbon intensity. The exact extent of

potential savings in CO₂ emissions that might result from these policy measures, both in isolation or combined, is extremely difficult to quantify.

Overall assessment of the potential impact of public policy measures on the key freight parameters is complicated by the fact that some of the policy measures may have very complex and sometimes contradictory outcomes. Table 7.15 presents a range of policies and indicates their potential impacts on the main freight parameters. The policy measures listed in the table can be classified into the following categories:

- Measures designed to make road less attractive (mostly fiscal measures such as taxes on vehicle ownership, fuel duties or road charging schemes).
- Measures to make rail more attractive (including fiscal, operational and infrastructural measures as well as regulatory changes).
- Measures to improve road traffic flow (e.g. investment in road infrastructure, improved road traffic management, relaxation of night curfews and/or access restrictions, improved and integrated land-use and transport planning policies).
- Measures to control emission levels (e.g. emission standards on trucks / rail, reduction in speed limits and mandatory speed governors on trucks).
- Advice and exhortation (e.g. advice on sustainable logistics, benchmarking programmes, accreditation schemes or subsidised driver training initiatives).

To achieve significant savings in CO₂ emissions from road freight transport, governments need to apply a bundle of measures presented in this section. At the policy planning stage the main problem lies in the quantification of the potential CO₂ reductions from a given ‘portfolio’ of policy measures. In the logistics literature, the attempts to assess the CO₂ savings resulting from different policy options are still very limited. This is because most of the measures will not be applied in isolation. Thus, the magnitude of expected CO₂ savings will be dependent both on the combination of initiatives proposed and also on the policy measures already in place. Also the economic cost-benefit analysis of potential solutions is important. The carbon abatement cost curves, presented in Chapter 2, can prove a very useful tool to assess the effectiveness of different policy options. However, as discussed before, their application in freight-related policy appraisal is still rather limited.

Policy measure	Freight transport intensity	Modal split (road %)	Vehicle utilisation ¹	Energy efficiency
Higher truck taxation	↓	↓	↑	↑
Higher fuel duty	↓	↓	↑	↑
Introduction of road user charging	↓	↓	↑	↑
Deregulation of road freight sector	↑	↑	↑	↑
Liberalisation of rail freight market	↑	↓	↑	↑
Standardisation of rail equipment	↑	↓	↑	↑
Improved inter-operability of rail systems	↑	↓	↑	↑
Rail infrastructure investment	↑	↓		↑
Increased revenue support for rail track access	↑	↓		↑
Grants for rail-sidings / equipment	↑	↓		↑
Road infrastructure investment	↑	↑		↑
Improved road traffic management	↑	↑	↑	↑
Relaxation of night curfews / access restrictions	↑	↑	↑	↑
R&D support for truck design	↑	↑	↑	↑
Higher truck weight / size limits	↑	↑	↑	↑
Tighter emission controls on trucks	↓	↓		↓
Tighter emission controls on rail	↓	↑		↓
Reduction in speed limits		↓	↓	↑
Mandatory speed governors on trucks		↓	↓	↑
Improved land-use / transport planning	↓	↓		↑
Subsidised driver training schemes	↑	↑		↑
Advice / promotion on sustainable logistics	↓	↓	↑	↑
Mandatory fuel efficiency standards				↑
Benchmarking programmes			↑	↑
Accreditation schemes for trucking companies			↑	↑
Multi-stakeholder freight initiatives	↓	↓	↑	↑

¹ road vehicles and rail wagons

Table 7.15. The impact of policy measures on freight
Source: International Energy Agency, 2009

7.6. Conclusions

The future impact of changes in key logistics parameters on freight-related energy consumption and emissions is difficult to quantify. In this Chapter, an attempt has been made to produce a forecast of CO₂ emissions from HGVs in Great Britain using a spreadsheet-based forecasting model and calibrating it with the Delphi experts' opinions on future developments in logistics and freight transport trends.

The mid-range BAU scenario indicates that the most likely outcome in 2020 is a marginal reduction in CO₂ emissions from road freight transport of around 10%. This would occur despite an increase of 21% in the amount of road freight movement above the 2007 level. Substantial improvements in vehicle utilisation and fuel efficiency and shifts to alternative transport modes and lower carbon fuels would more than offset the effect of this growth in road tonne-kms on CO₂ emissions. The optimistic and pessimistic scenarios, defined by a one standard deviation range on either side of the mean Delphi scores, envisage road-freight-related CO₂ emissions falling by 47% or rising by 56%.

Some interesting results emerged while comparing the Delphi-derived forecasts to other projections available in the published literature. The total freight tonne-kms in our BAU scenario are only marginally different from the estimate based on the Mobility 2030 report (325 and 318 billion tonne-kms in 2020, respectively). The projections of truck tonne-kms envisaged by the Delphi panellists are precisely the same as the estimates presented in the European Energy and Transport – Trends to 2030 report (195 billion tonne-kms in 2020). Also, the 5% improvement in fuel efficiency assumed in the BAU case is consistent with the Tremove projections (4.7%) and one of the scenarios in the National Transport Model (5.2%). As all these studies were conducted independently, using different methods, this adds corroboration to the findings presented in this thesis. Based on different projections available in the published literature, a range of CO₂ emission estimates was modelled to illustrate the scale of environmental impacts if these scenarios were to materialise.

If the optimistic Delphi-based projection proved accurate, the GB road freight sector would be on a trajectory that would comfortably meet the 80% CO₂ reduction that the UK government has set for the economy as a whole by 2050. If, however, the mid-range BAU forecast is adopted, as it reflects the majority opinion of the Delphi

panellists, the road freight sector will fall well short of the necessary ‘carbon pathway’ to an 80% CO₂ reduction by 2050 (or 21% by 2020). Government and business will then have to intensify their efforts to decarbonise the movement of freight by road by implementing appropriate policy measures. A number of alternative scenarios were modelled to illustrate the magnitude of changes required to meet the 2020 GHG emission reduction target.

The challenge facing public policy makers trying to design an optimal portfolio of carbon reducing measures for freight transport is that different options are likely to influence the various freight and logistical variables in a complex and often unpredictable way. More research is needed to quantify the impacts of different policy options on freight transport variables and the sector’s CO₂ emissions. The model presented in this Chapter offers two main benefits. First, the BAU scenario is presented. This provides a reliable baseline against which the effectiveness of future initiatives can be benchmarked. The model is also a useful tool constructing and comparing various scenarios, and offers the decision maker a possibility to assess the environmental consequences of policy interventions in this sector.

Chapter 8. Conclusions

Aims of the chapter:

- *To summarise the key findings of this research*
- *To emphasise academic and practical implications of this research*
- *To discuss limitations to the study*
- *To identify areas for further research*

Chapter 8 concludes this thesis relating the findings discussed in Chapters 5 to 7 back to the primary objective and research questions formulated in Chapter 1. The contribution of the thesis to the logistics and supply chain management literature is then presented and its practical implications highlighted. Finally, potential limitations are recognised and ideas for future research outlined.

8.1. Thesis Summary

Freight transport is vital to economic prosperity and growth. Raw materials, components and final products flow in vast quantities through complex supply chain systems to satisfy the demands of consumers. Although vital to ensuring economic prosperity, freight transport also poses a large burden on the physical environment and society. As discussed in Chapter 2, externalities such as air pollution, noise and vibrations, impact on land use and biodiversity, congestion, accidents or visual pollution, are typically not taken into account in a decision making process but can, in the longer-term, cause irreversible environmental damage and significantly compromise the quality of life. The environmental problems associated with freight transport are well researched in the literature (e.g. Kroon et al., 1991, Holman, 1996, Worsford and Blair, 1996) and legislation is in place to limit the external impacts (e.g. Euro emission standards, noise limits and regulations on the maximum weight and size of vehicles, etc.). Nevertheless, the true extent to which freight-related externalities can be minimised depends on the preparedness of individual businesses to recognise, acknowledge and mitigate the impacts of their transport activities.

Climate change and its potentially catastrophic consequences are now at the top of political agendas. The increasing concentrations of GHGs are leading to the gradual warming of the Earth's atmosphere. This is likely to cause a range of negative impacts on food and water supply, ecosystems, weather conditions, etc. (Stern, 2006). Emissions

of CO₂ and other GHGs from a number of sectors are now regulated by the Kyoto Protocol.

In the UK, road is the dominant freight transport mode carrying 65% of the total tonne-kms and 82% tonnes lifted in 2008 (Department for Transport, 2009b). This creates a large environmental problem as road is the second most energy intensive mode of freight transport (after air) (McKinnon, 2007b). At present, emissions from HGVs account for around 5-6% of total domestic CO₂ emissions. As discussed in Chapter 3, given the geographical attributes of the country and the high service quality and economic efficiency offered by road freight operators, road is expected to maintain its leading position on the UK freight transport market. Thus, while shifting more freight to less carbon intensive transport modes (i.e. inducing the relative decoupling of freight transport and economic growth in Verny's (2007) classification) is an important policy option, efforts should be focused on maximising the efficiency of goods movements by road. Also, unlike air pollutants and many other environmental impacts, CO₂ emissions from road freight transport still remain unregulated. What is more, they may further increase as a result of tighter emission controls on other pollutants (e.g. introduction of Euro 6 emission standard in 2013). Against this background, government is setting ambitious targets for carbon reduction which may soon be applied, a sectoral level, to freight transport. This research on the prediction of future trends in HGV-related CO₂ emissions is therefore particularly timely.

On the basis of a comprehensive literature review the complex relationships between different logistics variables were mapped and the theoretical framework underpinning this research developed. This framework links the aggregate outputs such as volume of goods moved, vehicle kms, fuel consumption and CO₂ emissions through a series of key logistics variables (e.g. share of road, average length of haul, lading factor, fuel efficiency etc.). A similar approach was previously adopted in studies such as REDEFINE. However, the framework had to be extended to illustrate the likely impacts of various factors both internal and external to the system in question. For the purpose of this research the factors potentially influencing CO₂ emissions from road freight transport were classified into six categories. Each category was then linked to the variables on which it impacted.

The results of the literature review were then validated through a series of seven focus group discussions. 58 participants representing six different types of organisation (i.e. producers, trade bodies, retailers, providers, enablers and policy makers) and 13 different industry sectors took part in the discussions. The main aim of this part of the research project was to ensure that the findings of the literature review were still applicable and to investigate any new factors that might have gained importance recently and are still not adequately reported in the literature. The discussions indicated that the logistics industry is aware of and concerned about the environmental impacts of freight transport activities and that more research and advice on the ways to improve the sustainability of operations would be welcomed. The combined results of the literature review and focus group research were used to develop a Delphi questionnaire survey.

The Delphi survey was carried out to validate, generalise and quantify the trends identified in the previous stages of the research. The two-round survey consulted a sample of 100 logistics and supply chain experts in order to elicit projections of future changes in the key logistics parameters and to explain why these changes are expected to occur. The panellists were asked to make the projections on a BAU basis. Statistical analysis of the responses revealed average opinions on the issues investigated and variability across the sample. The Delphi-derived projections were then input into a spreadsheet model to construct a forecast of CO₂ emissions from road freight transport in 2020.

The spreadsheet model was developed on the basis of the CSRGT freight data and calibrated initially for 2007 as a base year. The model quantifies the CO₂ emissions from HGVs using one of the approaches presented in McKinnon and Piecyk (2009). Average future values for the range of key logistics variables were then input into the model to re-calibrate it for 2020 and produce a forecast of future CO₂ emissions. In order to reduce the uncertainty associated with long-term forecasting, a number of alternative scenarios were also modelled. They were constructed using both the Delphi survey results and other projections obtained from the literature. Finally, the magnitude of savings in CO₂ emissions from truck activity that would be required to achieve the UK national GHG reduction target for 2020 was calculated. A number of scenarios capable of meeting this target were created to illustrate the scale of efforts necessary to ensure the long-term sustainability of the sector. Also, potential policy measures to

reinforce the reduction of CO₂ emissions from road freight transport were reviewed. The key findings of the research project are summarised below.

8.2. Key Findings

The main aim of this thesis, as stated in Chapter 1, was to produce a forecast of CO₂ emissions from road freight transport in Great Britain up to 2020 on a BAU basis. **This research indicates that, when the BAU scenario is considered, the carbon footprint of road freight transport is likely to decrease to 17.4 million tonnes of CO₂ in 2020. This represents a 10% reduction from the 2007 level.** In line with the main objective five research questions were developed in Chapter 1. The research questions are addressed below:

***RQ1:** What methodologies can be used to establish a BAU forecast of the environmental impact of road freight transport and what are their main advantages and disadvantages?*

There are only a limited number of published studies presenting long term projections of future volumes of freight transport, related energy use and/or CO₂ emissions. Most of the published forecasts relate to transport or road transport in general, focusing mostly on passenger traffic. This can be partly explained by the fact that emissions from cars still constitute the greatest proportion of the transport GHG emissions. For example, in 2007 HGVs contributed only 20% of total transport emissions in that year (Department for Transport 2009c).

Previous road freight forecasting studies have typically projected future trends on the assumption that freight transport, as a second-order activity, will be correlated to or lag behind some economic indices, most often GDP. Extrapolation of past trends is also a common practice. This makes the process relatively straightforward but the accuracy of road freight forecast becomes strongly dependent on the reliability of the projections of the changes in the underlying parameters. Also, as argued in Chapter 4, this approach is only appropriate when the past trends can be expected to endure. Analysis of government road freight statistics (Chapter 3) suggests, however, that the structure of freight transport growth has changed over the past 10-15 years and is no longer solely a function of economic growth but depends on a range of logistics variables. Hence, new approaches are needed that recognise the underlying causes of freight traffic growth and

incorporate a number of industry-related factors into the long-term forecasting of freight transport activity and related externalities. This leads to the next point.

RQ2: What are the main factors determining the environmental impact of road freight transport and how they are related?

The environmental impact of road freight transport (measured in this thesis in terms of CO₂ emissions) depends on the total demand for freight movement, proportion of freight traffic moved by road, structure of the distribution systems through which goods move, levels of vehicle utilisation as well as the type and amount of fuel used. These six factors were combined in an analytical framework linking freight transport volumes to related CO₂ emissions presented in Chapter 3.

Firstly, increasing the proportion of freight transported by other less energy-intensive modes will result in lower CO₂ emissions from road freight transport. Secondly, restructuring supply chains, reducing the number and average length of links between points of production and consumption reduces the transport intensity of an economy. Thirdly, raising the level of vehicle utilisation reduces the ratio of vehicle-kms to tonne-kms cutting the total distance travelled by HGVs. Finally, reducing total energy consumed in trucking and switching to lower carbon energy sources will cut CO₂ emissions per vehicle-km, reinforcing the other decarbonisation measures.

As a result, projections of future changes in variables such as modal split, average length of haul, handling factor, empty running, lading factor, fuel efficiency and carbon intensity should be incorporated into the forecast of CO₂ emissions from road freight transport. Each of these variables can be influenced by a number of driving forces originating from within the logistics system as well as from the external environment. These factors are discussed below (RQ4).

***RQ3:** From the logistics industry perspective, how are the main factors determining the environmental impact of road freight transport likely to change by 2020 on a BAU basis?*

Freight Modal Split

This research suggests that only a modest positive (i.e. from road to rail or water) change in modal split can be expected by 2020. During the focus group discussions, greater potential was seen for the expansion of waterborne transport than for rail. The development of short sea / coastal routes and increase in feeder movements to/from the deep sea ports were identified as the main factors supporting the growth of waterborne transport. The Delphi survey results, on the other hand, suggested a slightly different picture. The panellists expected road freight transport to have its market share reduced to 60% but mostly in favour of rail (+2.4%), followed by waterborne transport (+1.5%) and pipeline network (+0.3%). Thus, in the BAU scenario, the expected shares of alternative modes in 2020 are: rail 11%, waterborne transport 25% and pipeline 4%.

Regardless of which mode is expected to gain the greatest proportion of traffic displaced from road, the overall change would not be sufficient to achieve the target reductions in the CO₂ emissions. The modelling results suggest that, if all other parameters were to remain constant, a reduction of road's share to 47.5% of the freight tonne-kms would be required to achieve the CO₂ savings in line with the UK 2020 GHG reduction target. This percentage would be even lower if an allowance were made for some growth in total tonne-kms. Thus, to set the UK freight transport sector on the path to long-term sustainability, greater changes in modal split than those anticipated in the BAU scenario will be required. Investment in infrastructure, planning policies for more effective co-ordination of transport modes and an expansion of the Freight Facilities & Waterborne Freight Grant schemes were considered the most effective means of promoting modal shift. Fiscal measures, making road transport less attractive (such as higher duties on diesel fuel, road pricing schemes on HGVs or inclusion of the freight transport sector in the emission trading scheme) would also reinforce the positive trend envisaged in the BAU scenario.

Supply Chain Structure

Both focus group discussions and the Delphi survey participants indicated that the two key factors determining supply chain structures, i.e. handling factor and the average

length of haul, are going to remain relatively stable in the future. The focus group respondents also pointed out that the situation may differ between sectors. They were strongly convinced that recent changes in customers' environmental awareness and attitudes will promote more localised sourcing of products, hence lead to a reduction in the average length of haul, especially in the food sector. In the Delphi survey logistics managers from the retail sector were the group who predicted the strongest pressure to centralise inventory. Overall, the responses from the Delphi experts suggested only marginal changes in the average length of haul (a reduction by 1km to 86 kms) and no further changes in handling factor (i.e. a handling factor of 3.4) by 2020. This does not mean that no structural changes within supply chains will occur. As discussed above, supply chain structures are likely to be subject to a number of counteracting pressures which, on balance, may cause only small net shifts in the two supply chain structure determinants, i.e. handling factor and the average length of haul.

Vehicle Utilisation

It emerged from the focus group discussions that companies are already intensifying their efforts to improve utilisation of their fleets. This was confirmed by the Delphi survey participants. In the BAU scenario empty running is expected to decline to 22% (a reduction of 5%) and the lading factor to rise to 64% (an increase of 7%). As discussed in Chapters 3, 5 and 6, the levels of vehicle utilisation are primarily influenced by decisions made at the operational or functional levels in the logistical decision-making hierarchy.

The greater magnitude of expected improvements in vehicle utilisation, when compared with predicted trends in supply chain structures or modal split, can be explained by the relative flexibility with which companies can change their use of vehicle assets in the short- and medium-term. Also, the levels of empty running and vehicle loading are directly under the control of the companies and their partners in the supply chains, while changes in other parameters depend partly on the external developments. For example the degree of modal shift is likely to be conditional on the government's investment in infrastructure while changes in carbon intensity of alternative fuels will be affected by, among other things, external research and technological developments.

Fuel Efficiency and Carbon Intensity

Significant improvements in fuel efficiency by 2020 were expected by both focus group and Delphi survey participants. This will be largely a result of changes to vehicle design, information technology support, better engine performance, training schemes for truck drivers and the rescheduling of delivery operation to non-peak hours. High fuel prices will also be a significant factor promoting fuel management initiatives.

The carbon intensity of fuel is also anticipated to decrease by 2020, mainly through the use of biodiesel. The focus groups, nevertheless, expressed a great deal of concern about the availability and sustainability of biodiesel supplies. Increased vehicle maintenance costs and lower fuel efficiency (resulting in higher fuel bills and tailpipe CO₂ emissions) were listed as potential obstacles to the reduction of carbon intensity through a switch to biodiesel. Overall, the focus group discussions indicated a great deal of uncertainty and hesitancy about the effectiveness of measures to reduce carbon intensity. Consequently, it was decided to exclude this question from the Delphi survey. This also suggests that, as new technologies are being developed, advice, training and promotional schemes will be of crucial importance in communicating future green solutions to the logistics industry.

RQ4: Up to 2020 what will be the main drivers of the changes in these key factors?

As argued in Chapter 3, the logistical factors affecting freight transport activity can be classified into six categories. This was mirrored by adding two more categories to a framework originally devised by McKinnon and Woodburn (1993, 1996). Structural factors determine the number, location and capacity of facilities in the logistics system. Commercial factors relate to sourcing and distribution strategies. Operational factors affect the scheduling of product flow and functional factors influence the management of transport resources. Product-related factors relate to product, packaging or the configuration of handling equipment which can affect the logistical requirements. External factors arising outside the system include tax policy, oil prices or developments in vehicle technology. The complex interactions between all these factors determine the amount of road freight traffic as well as resulting fuel consumption and CO₂ emissions.

The structural factors which will exert the greatest influence on road freight transport up to 2020 include further offshoring of production capacity, primary consolidation initiatives and concentration of trade through hub ports and airports. Growth in online retailing, reverse logistics and outsourcing of non-core processes are the most important commercial factors likely to occur over this period. The most significant operational factors include increased frequency of night-time deliveries, greater variability of order sizes and shortening of order cycles. Use of telematics, vehicle routing and scheduling systems and logistical collaboration between companies are expected to be the dominant functional factors. Finally, fuel prices, availability of drivers and development of online freight exchanges and load matching services are the main external factors likely to affect road freight transport in the UK up to 2020.

The key trends influence more than one logistics variable with some having a pervasive effect on freight transport levels and related CO₂ impacts. Hence, the framework illustrating the links between the factors, road freight variables and related outputs has been shown to be of great value to both businesses and public policy makers.

RQ5: *What additional policy measures can be applied to reduce the CO₂ emissions from road freight transport?*

If the road freight transport sector were to cut its emissions in line with the UK 2050 GHG reduction target, this would require limiting the truck-related emissions to 14.5 million tonnes of CO₂ by 2020 (a 25% reduction from the 2007 level). As mentioned above, when the BAU scenario is considered, 17.4 million tonnes are likely to be emitted from HGVs in 2020 (a 10% reduction from the 2007 level). This is 2.9 million tonnes above the national target. Furthermore, only three of the scenarios based on the published literature are capable of meeting the 2020 target. All of them assume improvements in fuel efficiency and the carbon intensity far greater than the BAU case. Nevertheless, the optimistic scenario derived from the Delphi results, offers sufficient savings for the road freight sector to comfortably meet the 2020 target. This suggests that although challenging, the required reductions in CO₂ emissions are still within reach but new policy initiatives will be required to reinforce the positive BAU trend. A number of sample scenarios were presented to illustrate what changes in the key road freight transport would be needed to achieve the 2020 target.

A wide range of public policy measures have already been applied to reduce the CO₂ emissions from road freight transport. These are incorporated in the BAU scenario. New initiatives are necessary if savings exceeding the 10% reduction projected in the BAU case are required. The new policy measures should be targeted at the key freight transport variables in the theoretical framework.

Designing an effective portfolio of policy initiatives is not straightforward. As explained in Chapter 7, potential policy measures have complex and sometimes contradictory effects. Overall, a successful 'bundle' of policy options should comprise measures designed to improve the attractiveness of alternative, less-energy intensive freight transport modes, reduce the relative attractiveness of road transport, improve traffic flow, control emission levels and encourage businesses to implement initiatives aimed at better utilisation of vehicles and more effective fuel management.

8.3. Contribution of the Thesis

Through a comprehensive investigation of future trends in the key logistics variables, factors shaping them and the complex inter-relations between these factors and variables, this thesis has made a significant contribution to the logistics literature and the general body of knowledge. No previous study has focused specifically on forecasting of CO₂ emissions from road freight transport on the basis of expert opinion within the sector. As discussed in Chapter 3, most studies link transport volumes to generic economic indices such as GDP. Although the need to disaggregate this link between generic economic indicators and freight transport volumes has been acknowledged (e.g. McKinnon, 1998b, Voordijk, 1999, Drewes-Nielsen et al., 2003), there have been no previous attempts to built up a forecast of road freight traffic and related CO₂ emissions from separate projections of the future course trends in component logistics variables.

Chapters 2 and 3 provide a comprehensive literature review of issues relating to the relatively new field of green logistics. The theoretical framework is then introduced that advances the approach adopted in the previous studies. It not only links the main outputs and variables but also adds the main structural, commercial, operational, functional, product-related and external factors into the equation. These factors are likely to be a result of decisions made at different levels in the decision-making hierarchy. Thus, it provides a link to management theory and constitutes a formal

assessment framework showing how various decisions will affect the key logistics variables and, in turn, impact on outputs like traffic levels, fuel consumption, CO₂ emissions, etc.

From a methodological perspective (Chapter 4) there are several contributions. It was decided to move away from the traditional positivistic approach and adopt the critical realism paradigm to add depth to the exploration of factors behind the investigated phenomenon. This is still a relatively innovative approach to logistics research. This research represents also the first application of the critical realist approach to long-term freight modelling. Detailed reviews of focus group and Delphi research applications in the discipline of logistics are also included in the Chapter. The focus group research presented in this thesis has already been used to co-author a paper on application of focus groups as a method for collecting data in logistics (Sanchez-Rodrigues et al., 2010). Both focus group and Delphi-based survey methods were combined through the course of the research providing innovative approach to expert-based forecasting in the field of logistics and freight transport.

The contribution of Chapters 5 and 6 lies in an in-depth investigation of future changes in the key logistics variables and factors behind them. This is a first study to consult a large sample of logistics and supply chain experts (58 in focus group discussions and 100 in the Delphi survey) on the future impact of logistics trends on freight-related CO₂ emissions. This study is also unique in covering such a wide range of logistics variables and factors shaping them. Although there are some projections on e.g. modal split, road tonne-kms or vehicle kms attempted in the literature, this research is the first to elicit forecasts of changes in other key parameters such as lading factor and handling factor. Also, the identification, classification and quantification of structural, commercial, organisational, functional, product-related and external factors influencing the road freight transport system should assist the development of evidence-based policy-making in this field.

The modelling work presented in Chapter 7 represents a major contribution to the literature by eliciting a detailed forecast of CO₂ emissions from HGVs in 2020. The BAU scenario is of particular importance here, as it represents a baseline or reference projection of future CO₂ levels from the road freight sector, not previously available in the literature. This Chapter also shows the magnitude of emission savings required in

the sector to achieve reductions in line with the UK target and constructs sample scenarios that would be capable of meeting the 2020 target. This clearly adds to the existing body of knowledge and will be of value to policy and decision makers. This and other practical implications of this research are discussed in the next section.

8.4. Practical Implication of the Research

As decision makers are becoming increasingly aware of the environmental burden the freight transport activities impose, this thesis has potentially a high practical relevance. Firstly, it provides policy makers with baseline projections of future CO₂ emissions from road freight transport. It also presents a framework for assessing the likely changes to these baseline scenarios resulting from various policy measures. The research improves understanding of these trends which, from the industry perspective, are likely to exert the greatest influence on the UK road freight transport sector. Some of the results of the Delphi survey, which were published in an earlier research report, were reported in the government's strategy document, *Delivering A Sustainable Transport System - The Logistics Perspective* document (Department for Transport, 2008a). This confirms that the results have already entered the policy-making process.

The framework presented in this thesis can also be applied at the micro-scale, to serve the needs of an individual company. As it links the volumes of products moved to freight traffic levels and associated CO₂ emissions, it can be used to develop a sustainable logistics strategy and monitor environmental performance. Also, by raising the awareness of future trends likely to affect the sector the research provides companies with a better base for a long term planning and the development of carbon reduction strategies.

8.5. Limitations of the Research

Although this research was designed and executed in a careful and rigorous manner, a researcher inevitably operates within certain constraints. Hence, some limitations to the findings exist and it is important to be aware of them.

The general limitations associated with the forecasting methods adopted in this thesis were discussed in detail in Chapter 4. Also, ways in which the different parts of this research project could be affected were considered in the relevant Chapters. As with all long-term forecasting there is a risk of an unforeseen event occurring. If the event is

large enough to radically change the ways in which the road freight transport sector operates, it may affect the accuracy of results. Although the risk of overlooking a major eventuality was minimised by ensuring a large and diverse sample of participants, it should be acknowledged that the possibility still exists. Thus, the forecasts may need to be updated in the event of a sudden unforeseen change in the business environment.

The main aim of this research was to produce a forecast of road freight transport-related CO₂ emissions up to 2020 on a BAU basis. As explained before, the BAU scenario assumes the absence of any new policy initiatives, i.e. continuity of the current external environment in which businesses operate. However, there are always some policy measures being ‘in the pipeline’, i.e. planned and approved but not implemented at the time when the study was underway. There may be also measures already implemented but whose full effects were yet to be experienced at the time of the surveys. Hence, respondents had to make judgements of the longer term effects of such policy interventions. These problems relate to all BAU studies and, as it is impossible to fully isolate a policy-free environment for the purpose of research, it cannot be completely eliminated.

This study focused on road freight sector as a whole without differentiating the industries within which the transport activities are undertaken. The nature and scale of the future logistics trends are likely to vary by sector. Contributors’ experience of particular sector will inevitably influence their view of general road freight trends. A better understanding of how individual trends are going to develop within different industry sectors could help to target potential future solutions and measures to the specifics of road freight transport in these sectors.

Finally, this thesis focused exclusively on goods moved by HGVs. CO₂ emissions from moving freight in vans were, therefore, excluded from the calculations. As freight tonne-kms moved by vans increased by 267% between 1980 and 2008 and tonnes lifted grew by 85% over the same period (Department for Transport, 2009b), vans are becoming a considerable source of CO₂ emissions from road freight transport. The increasing role of vans moving freight was also acknowledged during the focus group discussions and expected to continue. Future research projects should investigate CO₂ emissions from all road freight transport activity including van traffic. This and other possible directions for future research are presented in the next section.

8.6. Directions for Future Research

This study focused on the future CO₂ emissions from road freight transport and the key factors likely to affect them in the coming years. As such, this thesis is a good starting point for future research some of which could address the limitations listed above. Industry sector-specific analysis of the key logistics trends and/or inclusion of vans in the analysis would definitely add extra value to the green logistics literature.

Apart from these two, there are several other ways in which this study could be advanced further. First, a follow-up research project could be extended to other transport modes. The framework introduced in this thesis could be tailored to the specifics of rail, waterborne and air freight transport. Application to the pipeline network would probably be rather limited due to the characteristics of the mode, particularly the limited range of products carried. A comprehensive framework could be developed covering the freight transport as a whole. Such a model would be very helpful in illustrating the consequences of any decision made to the whole freight transport system, helping to optimise its overall performance.

Further, not only other transport modes but also other logistical activities like e.g. storage, materials handling, order picking and packing etc., could be incorporated at a later stage. This would provide a comprehensive view of the carbon footprint of the logistics activity.

Partly related to the previous point would be inclusion of other GHGs in the assessment. As CO₂ constitutes 96% of the total GHG emissions from road freight transport (Choudrie et al., 2008), it was deemed appropriate to focus solely on the CO₂ element in this thesis. However, if other modes or, particularly, other logistical activities were to be included, the assessment should be extended to the whole range of GHGs as they tend to emit a larger proportion of GHGs other than CO₂ (e.g. perfluorocarbons and hydrofluorocarbons from refrigeration equipment).

The next step would be then to extend the research to include all external impacts (e.g. air pollution, accidents, noise, etc. as listed in detail in Chapter 2) associated with freight transport and other logistics activities. These impacts could be also expressed in monetary values to ensure their comparability. From a societal perspective, the awareness of the full external cost should help businesses and individuals to appreciate

the full scale of freight transport's / logistics' impact on the environment. This knowledge should increase sensitivity to the environmental aspect of distribution operations and encourage businesses and consumers to make more responsible choices.

Future research could also replicate this study in other countries or regions. This can be somewhat limited by availability of the necessary freight transport data (McKinnon and Leonardi, 2009, Piecyk and McKinnon, 2009a). Nevertheless, it could result in some interesting comparisons between different parts of Europe or even other continents.

The final line of further enquiry would be to investigate in greater detail the policy options for reducing CO₂ emissions. Although measures offering the potential to improve the environmental performance of the sector were briefly presented in Chapter 7, there is a great deal of uncertainty about their impact and cost-effectiveness. Thus future studies focusing on quantification of the potential impacts of various policy measures would be of a particular value.

8.7. Summary

This Chapter concludes the thesis summarising the key findings and highlighting the contributions of this research to academic body of knowledge as well as to industrial practice. The potential limitations to this research were also recognised and directions for further enquiry identified.

Overall, only a modest 10% reduction in CO₂ emissions associated with road freight transport by 2020 can be expected in the absence of any new policy initiatives or increased market pressures. Establishing this baseline projection is of crucial importance as, until now, there has been no detailed forecast compiled specifically for the road freight transport sector. The 10% reduction, however, will not be enough if the sector is expected to reduce its carbon intensity in line with the overall national GHG reduction target. Thus, additional policy measures and other incentives will be required to augment the savings identified in the BAU scenario. The model developed for the purpose of this research can be used to assess the effectiveness of such measures providing decision makers with reliable estimates of their impact on future CO₂ emission levels. Therefore, this thesis represents a significant contribution to the academic literature as well as offering practical messages for policy makers and managers.

Appendix A. First Round Delphi Questionnaire



Green Logistics Project

Understanding and Forecasting Business-as-Usual Trends in Freight Transport and Logistics

The purpose of this survey is to improve our understanding of the complex interrelationships that exist between freight transport and logistics trends and to forecast their future direction.

In a series of seven focus group workshops held in the Spring 2007, industry representatives identified factors influencing these trends. We are now inviting a larger group of freight and logistics specialists to use their expert judgment to assess the importance of these factors and predict future trends up to 2020. The information collected will be used to forecast the economic and environmental impact of freight transport in the UK over the next 12 years. These forecasts will be made on a business-as-usual basis, assuming that there will be no new government policy initiatives over this period.

We would like to invite you to join our expert panel for this study. This will involve completing two rounds of a questionnaire survey. The questionnaire aims to canvass expert opinion on future trends in key freight and logistics parameters. The results of the first survey will be analysed and circulated to you along with a second copy of the questionnaire. You can then take account of the average scores in the first round when completing the second questionnaire. By recycling the results in this way it should be possible to achieve a higher degree of consensus across the panel.

This research is being undertaken as part of the Green Logistics project funded by the Engineering and Physical Science Engineering Council (EPSRC). For more information on the Green Logistics project, please visit...

www.greenlogistics.org

Start Survey

This questionnaire consists of 21 questions and will take approximately 30 minutes to complete.

All responses will be treated as strictly confidential and aggregated for analytical purposes.
All participants will receive a final report summarizing the results of the surveys.



Freight and Logistics Trends Survey



Personal Information

Your views expressed in this questionnaire will remain anonymous and confidential.

However, identification of respondents is necessary to conduct the second round of the survey. We guarantee that your personal details will only be used for this purpose and will not be shared with any third parties.

Please complete this section:

Name

Position

Email

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1 To what extent will the following changes to logistics and supply chain systems occur within UK by 2020?

(Please rate where 0 =not at all and 4 = large extent)

	0	1	2	3	4
Centralisation of production	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Decentralisation of production	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Centralisation of inventory	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Decentralisation of inventory	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Relocation of production capacity to other countries	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Relocation of warehousing to other countries	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Concentration of trade through hub ports / airports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Growth of hub & spoke networks (e.g. for parcels / pallet loads)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Development of urban consolidation centres	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Primary consolidation of inbound loads to distribution centres / factories	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Increasing the storage area at retail outlets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Reducing the storage area at retail outlets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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2 How are the following commercial practices likely to change by 2020?

(Please rate where -2 =much less important than now and 2 = much more important than now)

	-2	-1	0	1	2
Subcontracting of non-core processes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Global sourcing of supplies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Localised sourcing of supplies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Expansion of the market areas of UK businesses	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Online retailing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Return of products for reuse / recycling	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Retailer control of the supply chain	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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3 Relative to today how are the following logistics and supply chain operation likely to change by 2020?

(Please rate where -2 = large reduction, 2 = large increase)

	-2	-1	0	1	2
Order lead times	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Application of JIT principle	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Variability of order size	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Width of delivery time windows	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Frequency of delivery to shops	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Night-time delivery to retail outlets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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4 What will be the uptake of the following management practices by 2020 relative to today?

(Please rate where -2 = much less and 2 = much more)

	-2	-1	0	1	2
Focus on service quality rather than costs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Logistical collaboration between companies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Integration of production and distribution	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Matching of vehicle fleet to transport demands	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Investment in double-deck / high-cube vehicles	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use of vans for deliveries	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Backloading of vehicles	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use of vehicle routing and scheduling systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use of telematics	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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5 What will be the impact of the following external factors on the UK road freight transport by 2020?

(Please rate where -2 = large negative impact and 2 = large positive impact)

	-2	-1	0	1	2
Restrictions on drivers' time	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Availability of drivers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Introduction of user charging on the national road network	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Congestion charging in urban areas	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Quality of road infrastructure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Competition from foreign operators	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fuel prices	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Development of online freight exchanges / load matching services	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Polarisation of the road freight market	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Extension of emission trading scheme to freight transport	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use of alternative fuels	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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6 To what extent will the following changes in product and packaging design occur within UK by 2020?

(Please rate where 0 = not at all and 4 = large extent)

	0	1	2	3	4
Increase in the use of shelf-ready packaging	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Greater use of space-efficient packaging / handling equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Import of goods in store-ready format	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Miniaturisation of products	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Increase in the value-density of products (ratio of value to weight)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Design of products more sensitive to logistical requirements	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

7 Over the past 10 years UK Gross Domestic Product (GDP) has been growing at a much faster rate than road tonne-kilometres. How do you think road tonne-kilometres will grow up to 2020 compared to GDP?

(please rate where -2 = much slower, 0 = same rate, 2 = much faster)

-2	-1	0	1	2
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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- 8 By how much do you think the amount of freight traffic will change by 2020 in terms of total tonne-kms carried by all modes within the UK ?

(current situation = 100, higher values represent more tonne-kilometres)

	current	2020
Total tonne-kilometres	100	<input type="text"/>

- 9 How are the following road freight parameters likely to change between now and 2020?

	Now	2020
Average length of road haul	87km	<input type="text"/> km
Average number of links in supply chain for goods transported by road	3.4	<input type="text"/>
Lading factor (ratio of the tonne-kilometres that a vehicle actually carries to the tonne-kilometres it could have carried if it was running at its maximum gross weight)	57%	<input type="text"/> %
Empty running (as a percentage of the total lorry kilometres run)	27%	<input type="text"/> %

- 10 What is the likely change in the following factors going to be between now and 2020?

(Please rate where -2 = large decrease and 2 = large increase)

	-2	-1	0	1	2
Fuel efficiency (the vehicle-kms per litre of fuel)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Carbon intensity of fuel (the amount of CO2 emitted per litre of fuel used)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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- 11 What do you think the share of each transport mode expressed in terms of tonne-kms will be in 2020?

(Percentages must add up to 100%)

	Now	2020
Share of road	64%	<input type="text"/> %
Share of railfreight	9%	<input type="text"/> %
Share of inland waterways/coastal shipping	23%	<input type="text"/> %
Share of pipeline	4%	<input type="text"/> %
Total	100%	100%

- 12 How will the value, in real terms, of 1 tonne of product moved by the following modes to, from and within UK change by 2020?

(Please rate where -2 = large decrease and 2 = large increase)

	-2	-1	0	1	2
Road	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Rail	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inland waterway / coastal shipping	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Deep sea shipping	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Airfreight	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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13 To what extent will the amount carried by rail by 2020 be influenced by the following factors?

Please rate where 0 = not at all and 4 = large extent)

	0	1	2	3	4
Reliability	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Speed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Congested rail infrastructure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Flexibility	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Accessibility of terminals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bureaucracy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Additional handling involved	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Commodity mix	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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14 How effective would the following Government measures be in increasing rail's share of the UK freight market?

(Please rate where 0 = no effect and 4 = very effective)

	0	1	2	3	4
Upgrading rail infrastructure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Introduction of a road pricing scheme for HGVs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Expanding Freight Facilities Grant scheme	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Revenue support for Channel Tunnel connections	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Provision of dedicated rail freight routes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Promotion of best practice in company freight management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Planning policies for more effective co-ordination of transport modes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Higher duties on diesel fuel	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Extending emissions trading scheme to freight transport	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Enforcing regulations on road freight operators more rigorously	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Simplifying administrative / regulatory framework for rail freight	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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15 To what extent will the amount carried by coastal / short-sea shipping by 2020 be influenced by the following factors?

(Please rate where 0 = not at all and 4 = large extent)

	0	1	2	3	4
Reliability	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Speed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Congested port infrastructure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Flexibility	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Accessibility of ports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bureaucracy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Additional handling involved	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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16 How effective would the following Government measures be in increasing coastal /short sea shipping's share of the UK freight market?

(Please rate where 0 = no effect and 4 = very effective)

	0	1	2	3	4
Upgrading port infrastructure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Introduction of a road pricing scheme for HGVs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Expanding Waterborne Freight Grant scheme	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Promotion of best practice in company freight management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Planning policies for more effective co-ordination of transport modes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Higher duties on diesel fuel	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Extending emissions trading scheme to freight transport	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Enforcing regulations on road freight operators more rigorously	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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17 Overall, how are the constraints on using rail and shipping services likely to change by 2020?

(Please rate where -2 = constraints significantly easing, 2 = constraints significantly tightening)

	-2	-1	0	1	2
Railfreight services	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Short-sea / coastal shipping services	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

18 Please rate the likely effectiveness of the following means of improving the fuel efficiency of freight transport operations by 2020.

(Please rate where 0 = no importance and 4 = very important)

	0	1	2	3	4
Training schemes for fuel efficient driving	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Higher fuel prices	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dissemination of best practice in fuel management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
'Out of hours' delivery operation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Information technology (telematics / vehicle routing software)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vehicle design	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Incentive schemes for employees	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Improved vehicle maintenance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Engine performance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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19 To what extent has concern about climate change forced your company to modify its freight transport operations in last three years?

(Please rate where 0 = not at all and 4 = large extent)

0	1	2	3	4	N/A
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

20 To what extent will concern about climate change force your company to modify its freight transport operations in the future?

(Please rate where 0 = not at all and 4 = large extent)

	0	1	2	3	4	N/A
by 2010	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
by 2015	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
by 2020	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

21 Please list any other important issues which you feel have not been addressed by the questionnaire.

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Submit

To complete and return the survey please click on the submit button...

Appendix B. Second Round Delphi Questionnaire



Welcome Back:

Understanding and Forecasting Business-as-Usual Trends in Freight Transport and Logistics

The purpose of this survey is to improve our understanding of the complex interrelationships that exist between freight transport and logistics trends and to forecast their future direction.

Several months ago you very kindly joined an expert panel by completing an online questionnaire about future freight and logistics trends. This study, which is being undertaken as part of the Green Logistics research project, is trying to forecast future trends in freight transport and its impact on the environment up to the year 2020. We were delighted by the response to this survey. We received exactly one hundred completed questionnaires from a broad range of specialists with differing perspectives on the freight and logistics sector.



You may recall that this is a two-stage survey in which all panel members get an opportunity to change their answers in the light of average responses of the panel as a whole. The average results for each question have now been calculated and inserted into the attached questionnaire along with your original answers. We would be grateful if you could compare your answers with the panel averages and decide if you would like to change any of your responses. You are under no pressure to do so. It is possible, however, that on reflection you might like to change your mind on some of the issues. Please enter all answers again even if you decide not to change them.

We are sure that you will find the results of the first round of the survey interesting and hope that you can find the time to help us to complete this second round. Once we have analysed all the results we will send you a summary report.

This research is being undertaken as part of the Green Logistics project funded by the Engineering and Physical Science Engineering Council (EPSRC). For more information on the Green Logistics project, please visit... www.greenlogistics.org

Start Survey *This questionnaire consists of 21 questions and will take approximately 30 minutes to complete.*

All responses will be treated as strictly confidential and aggregated for analytical purposes.
All participants will receive a final report summarizing the results of the surveys.



Freight and Logistics Trends Survey

Personal Information

Your views expressed in this questionnaire will remain anonymous and confidential.

However, identification of respondents is necessary to conduct the second round of the survey. We guarantee that your personal details will only be used for this purpose and will not be shared with any third parties.

Please complete this section:

Name

Position

Email

Your previous answers will be in blue
Average responses submitted will be in black

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1 To what extent will the following changes to logistics and supply chain systems occur within UK by 2020?

(Please rate where 0 =not at all and 4 = large extent)

	0	1	2	3	4	Your previous responses	
Centralisation of production	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3	2.2
Decentralisation of production	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.5
Centralisation of inventory	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3	2.3
Decentralisation of inventory	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.5
Relocation of production capacity to other countries	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	4	3.0
Relocation of warehousing to other countries	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.6
Concentration of trade through hub ports / airports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3	2.7
Growth of hub & spoke networks (e.g. for parcels / pallet loads)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	2.6
Development of urban consolidation centres	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	2.6
Primary consolidation of inbound loads to distribution centres / factories	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3	2.8
Increasing the storage area at retail outlets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.1
Reducing the storage area at retail outlets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	2.4
							Average responses

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2 How are the following commercial practices likely to change by 2020?

(Please rate where -2 =much less important than now and 2 = much more important than now)

	-2	-1	0	1	2		
Subcontracting of non-core processes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.0
Global sourcing of supplies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	0.9
Localised sourcing of supplies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-1	0.4
Expansion of the market areas of UK businesses	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-1	0.8
Online retailing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	1.6
Return of products for reuse / recycling	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	1.6
Retailer control of the supply chain	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	0.8

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3 Relative to today how are the following logistics and supply chain operation likely to change by 2020?

(Please rate where -2 = large reduction, 2 = large increase)

	-2	-1	0	1	2		
Order lead times	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	-0.4
Application of JIT principle	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-1	0.5
Variability of order size	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	0.8
Width of delivery time windows	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-1	-0.2
Frequency of delivery to shops	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	0.3
Night-time delivery to retail outlets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.1

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4 What will be the uptake of the following management practices by 2020 relative to today?

(Please rate where -2 = much less and 2 = much more)

	-2	-1	0	1	2		
Focus on service quality rather than costs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	0.5
Logistical collaboration between companies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	1.3
Integration of production and distribution	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	0.8
Matching of vehicle fleet to transport demands	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.0
Investment in double-deck / high-cube vehicles	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.2
Use of vans for deliveries	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	0.7
Backloading of vehicles	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.2
Use of vehicle routing and scheduling systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.3
Use of telematics	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.4

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5 What will be the impact of the following external factors on the UK road freight transport by 2020?

(Please rate where -2 = large negative impact and 2 = large positive impact)

	-2	-1	0	1	2		
Restrictions on drivers' time	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-1	-0.5
Availability of drivers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-1	-0.6
Introduction of user charging on the national road network	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-2	-0.2
Congestion charging in urban areas	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-2	-0.2
Quality of road infrastructure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-2	-0.2
Competition from foreign operators	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-1	-0.4
Fuel prices	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-1	-0.9
Development of online freight exchanges / load matching services	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	0.7
Polarisation of the road freight market	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	0.2
Extension of emission trading scheme to freight transport	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-1	0.2
Use of alternative fuels	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	0.7

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6 To what extent will the following changes in product and packaging design occur within UK by 2020?

(Please rate where 0 = not at all and 4 = large extent)

	0	1	2	3	4		
Increase in the use of shelf-ready packaging	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	2.6
Greater use of space-efficient packaging / handling equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3	2.9
Import of goods in store-ready format	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3	2.6
Miniaturisation of products	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	2.1
Increase in the value-density of products (ratio of value to weight)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	2.3
Design of products more sensitive to logistical requirements	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	2.1

-2 -1 0 1 2

7 Over the past 10 years UK Gross Domestic Product (GDP) has been growing at a much faster rate than road tonne-kilometres. How do you think road tonne-kilometres will grow up to 2020 compared to GDP?

☐ ☐ ☐ ☐ ☐ -1 -0.5

(please rate where -2 = much slower, 0 = same rate, 2 = much faster)

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- 8 By how much do you think the amount of freight traffic will change by 2020 in terms of total tonne-kms carried by all modes within the UK ?

(current situation = 100, higher values represent more tonne-kilometres)

	current	2020	
Total tonne-kilometres	100	<input type="text" value="120"/>	125.5

- 9 How are the following road freight parameters likely to change between now and 2020?

	Now	2020	
Average length of road haul	87km	<input type="text" value="100"/>	85.9
Average number of links in supply chain for goods transported by road	3.4	<input type="text" value="4"/>	3.4
Lading factor (ratio of the tonne-kilometres that a vehicle actually carries to the tonne-kilometres it could have carried if it was running at its maximum gross weight)	57%	<input type="text" value="60"/>	63.8
Empty running (as a percentage of the total lorry kilometres run)	27%	<input type="text" value="25"/>	22.1

- 10 What is the likely change in the following factors going to be between now and 2020?

(Please rate where -2 = large decrease and 2 = large increase)

	-2	-1	0	1	2	
Fuel efficiency (the vehicle-kms per litre of fuel)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	1.1
Carbon intensity of fuel (the amount of CO2 emitted per litre of fuel used)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	-0.7

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- 11 What do you think the share of each transport mode expressed in terms of tonne-kms will be in 2020?

(Percentages must add up to 100%)

	Now	2020	
Share of road	64%	<input type="text" value="60"/>	59.9
Share of railfreight	9%	<input type="text" value="10"/>	11.4
Share of inland waterways/coastal shipping	23%	<input type="text" value="25"/>	24.4
Share of pipeline	4%	<input type="text" value="5"/>	4.4
Total	100%	100%	

- 12 How will the value, in real terms, of 1 tonne of product moved by the following modes to, from and within UK change by 2020?

(Please rate where -2 = large decrease and 2 = large increase)

	-2	-1	0	1	2	
Road	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	0.4
Rail	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	0.4
Inland waterway / coastal shipping	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	0.1
Deep sea shipping	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	0.5
Airfreight	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	0.7

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13 To what extent will the amount carried by rail by 2020 be influenced by the following factors?

Please rate where 0 = not at all and 4 = large extent)

	0	1	2	3	4		
Reliability	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	1	3.1
Speed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	2	2.4
Congested rail infrastructure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	2	2.9
Flexibility	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	1	3.0
Accessibility of terminals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	1	3.0
Cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	2	3.0
Bureaucracy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	3	2.5
Additional handling involved	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	3	2.6
Commodity mix	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	1	2.1

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14 How effective would the following Government measures be in increasing rail's share of the UK freight market?

(Please rate where 0 = no effect and 4 = very effective)

	0	1	2	3	4		
Upgrading port infrastructure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	2	3.1
Introduction of a road pricing scheme for HGVs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	1	2.1
Expanding Freight Facilities Grant scheme	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	1	2.3
Revenue support for Channel Tunnel connections	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	3	2.2
Provision of dedicated rail freight routes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	2	2.9
Promotion of best practice in company freight management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	0	1.9
Planning policies for more effective co-ordination of transport modes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	0	2.3
Higher duties on diesel fuel	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	1	2.0
Extending emissions trading scheme to freight transport	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	0	2.0
Enforcing regulations on road freight operators more rigorously	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	2	1.5
Simplifying administrative / regulatory framework for rail freight	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	2	2.2

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15 To what extent will the amount carried by coastal / short-sea shipping by 2020 be influenced by the following factors?

(Please rate where 0 = not at all and 4 = large extent)

	0	1	2	3	4		
Reliability	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	2.6
Speed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	2.4
Congested port infrastructure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	2.6
Flexibility	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	2.5
Accessibility of ports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	2.6
Cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	2.8
Bureaucracy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	1.9
Additional handling involved	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	2.3

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16 How effective would the following Government measures be in increasing coastal /short sea shipping's share of the UK freight market?

(Please rate where 0 = no effect and 4 = very effective)

	0	1	2	3	4		
Upgrading port infrastructure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	2.6
Introduction of a road pricing scheme for HGVs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.8
Expanding Waterborne Freight Grant scheme	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	2.2
Promotion of best practice in company freight management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	1.6
Planning policies for more effective co-ordination of transport modes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	2.1
Higher duties on diesel fuel	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	1.7
Extending emissions trading scheme to freight transport	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	1.6
Enforcing regulations on road freight operators more rigorously	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	1.3

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17 Overall, how are the constraints on using rail and shipping services likely to change by 2020?

(Please rate where -2 = constraints significantly easing, 2 = constraints significantly tightening)

	-2	-1	0	1	2		
Railfreight services	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-1	-0.3
Short-sea / coastal shipping services	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-1	-0.3

18 Please rate the likely effectiveness of the following means of improving the fuel efficiency of freight transport operations by 2020.

(Please rate where 0 = no importance and 4 = very important)

	0	1	2	3	4		
Training schemes for fuel efficient driving	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	2.7
Higher fuel prices	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	2.4
Dissemination of best practice in fuel management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	2.1
'Out of hours' delivery operation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	4	2.6
Information technology (telematics / vehicle routing software)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	2.7
Vehicle design	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	2.8
Incentive schemes for employees	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	2.2
Improved vehicle maintenance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	2.1
Engine performance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3	2.7

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19 To what extent has concern about climate change forced your company to modify its freight transport operations in last three years? ☐ ☐ ☐ ☐ ☐ ☐ NA 2.0

(Please rate where 0 = not at all and 4 = large extent)

20 To what extent will concern about climate change force your company to modify its freight transport operations in the future?

(Please rate where 0 = not at all and 4 = large extent)

	0	1	2	3	4	N/A	
by 2010	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NA 2.1
by 2015	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NA 2.6
by 2020	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NA 3.0

21 Please list any other important issues which you feel have not been addressed by the questionnaire.

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To complete and return the survey please click on the submit button...

Appendix C. Detailed results of the Delphi survey

Q1: To what extent will the following changes to logistics and supply chain systems occur within UK by 2020? (where 0 = not at all and 4 = large extent)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation¹
Centralisation of production	2.2	1.1	2.2	1.0	-9%
Decentralisation of production	1.5	1.1	1.6	1.1	-1%
Centralisation of inventory	2.3	1.1	2.2	1.1	-7%
Decentralisation of inventory	1.5	1.1	1.5	1.0	-1%
Relocation of production capacity to other countries	3.0	1.0	2.9	0.9	-10%
Relocation of warehousing to other countries	1.6	1.0	1.5	0.9	-10%
Concentration of trade through hub ports / airports	2.7	0.9	2.7	0.8	-14%
Growth of hub & spoke networks	2.6	0.9	2.6	0.9	-2%
Development of urban consolidation centres	2.6	1.0	2.6	0.9	-4%
Primary consolidation of inbound loads to distribution centres / factories	2.8	0.9	2.8	0.7	-17%
Increasing the storage area at retail outlets	1.1	1.1	1.1	1.0	-8%
Reducing the storage area at retail outlets	2.4	1.2	2.4	1.1	-11%

Table 1. Structural factors affecting road freight demand

¹ between rounds 1 and 2 of the survey

Q2: How are the following commercial practices likely to change by 2020? (where -2 = much less important than now and 2 = much more important than now)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Online retailing	1.6	0.6	1.7	0.6	-11%
Return of products for reuse / recycling	1.6	0.6	1.6	0.6	-8%
Global sourcing of supplies	0.9	1.0	0.9	0.9	-15%
Localised sourcing of supplies	0.4	0.9	0.3	0.9	-7%
Expansion of the market areas of UK businesses	0.8	0.8	0.8	0.7	-5%
Retailer control of the supply chain	0.8	0.9	0.9	0.7	-18%
Subcontracting of non-core processes	1.0	0.8	1.1	0.8	-6%

Table 2. Commercial factors affecting road freight demand

Q3: Relative to today how are the following logistics and supply chain operations likely to change by 2020? (where -2 = large reduction and 2 = large increase)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Order lead times	-0.4	1.0	-0.5	0.9	-10%
Width of delivery time windows	-0.2	1.1	-0.1	1.0	-6%
Frequency of delivery to shops	0.3	1.0	0.2	0.9	-5%
Application of JIT principle	0.5	1.0	0.4	0.9	-6%
Variability of order size	0.8	0.8	0.9	0.6	-16%
Night-time delivery to retail outlets	1.1	0.7	1.2	0.7	-7%

Table 3. Operational factors affecting road freight demand

Q4: What will be the uptake of the following management practices by 2020 relative to today? (where -2 = much less and 2 = much more)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Use of telematics	1.4	0.7	1.4	0.6	-10%
Use of vehicle routing and scheduling systems	1.3	0.7	1.4	0.7	0%
Logistical collaboration between companies	1.3	0.6	1.4	0.6	-4%
Integration of production and distribution	0.8	0.8	0.8	0.8	0%
Matching of vehicle fleet to transport demands	1.0	0.8	1.1	0.7	-16%
Investment in double-deck / high-cube vehicles	1.2	0.7	1.3	0.6	-8%
Use of vans for deliveries	0.7	1.0	0.7	0.9	-1%
Backloading of vehicles	1.2	0.6	1.3	0.7	1%
Focus on service quality rather than costs	0.5	0.9	0.5	0.8	-13%

Table 4. Functional factors affecting road freight demand

Q5: What will be the impact of the following external factors on the UK road freight transport by 2020? (where -2 = large negative impact and 2 = large positive impact)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Fuel prices	-0.9	1.3	-0.9	1.3	-1%
Extension of emission trading scheme to freight transport	0.2	1.1	0.2	1.0	-6%
Use of alternative fuels	0.7	0.9	0.6	0.9	1%
Introduction of user charging on the national road network	-0.2	1.2	-0.3	1.1	-9%
Congestion charging in urban areas	-0.2	1.2	-0.2	1.2	-5%
Quality of road infrastructure	-0.5	1.2	-0.5	1.0	-13%
Availability of drivers	-0.6	1.1	-0.7	1.0	-5%
Restrictions on drivers' time	-0.5	1.1	-0.5	1.0	-8%
Development of online freight exchanges / load matching services	0.7	0.7	0.7	0.7	-9%
Polarisation of the road freight market	0.2	0.8	0.2	0.8	-5%
Competition from foreign operators	-0.4	1.1	-0.4	1.0	-10%

Table 5. External factors affecting road freight demand

Q6: To what extent will the following changes in product and packaging design occur within UK by 2020? (where 0 = not at all and 4 = large extent)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Greater use of space-efficient packaging / handling equipment	2.9	0.8	2.9	0.8	-5%
Design of products more sensitive to logistical requirements	2.1	1.1	2.2	1.0	-11%
Increase in the use of shelf-ready packaging	2.6	1.0	2.6	0.9	-10%
Import of goods in store-ready format	2.6	0.9	2.7	0.8	-15%
Miniaturisation of products	2.1	1.1	2.1	0.9	-14%
Increase in the value-density of products	2.3	1.0	2.3	1.0	-8%

Table 6. Product-related factors affecting road freight demand

Q7: Over the past 10 years UK GDP has been growing at a much faster rate than road tonne-kms. How do you think road tonne-kms will grow up to 2020 compared to GDP? (where -2 = much slower, 0 = same rate, 2 = much faster)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Road tonne-kms growth compared to GDP	-0.5	1.0	-0.5	0.9	-5%

Table 7. Projected road tonne-kms growth compared to Gross Domestic Product (GDP) growth

Q8: By how much do you think the amount of freight traffic will change by 2020 in terms of total tonne-kms carried by all modes within the UK? (current situation = 100, higher values represent more tonne-kms)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Total tonne-kms	126.7	21.7	127.0	21.0	-3%

Table 8. Projected growth in total tonne-kms

Q9: How are the following road freight parameters likely to change between now and 2020?	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Average length of haul (km)	85.9	17.3	85.7	15.0	-13%
Average number of links in supply chain for goods transported by road	3.4	0.8	3.4	0.7	-11%
Lading factor	63.8	6.5	64.4	5.8	-11%
Empty running	22.1	5.0	21.9	4.3	-14%

Table 9. Projected changes in average length of haul, handling factor, lading factor and empty running

Q10: What is the likely change in the following factors going to be between now and 2020? (where -2 = large decrease and 2 = large increase)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Fuel efficiency	1.1	0.7	1.1	0.6	-16%
Carbon intensity of fuel	-0.7	1.1	-0.7	0.9	-14%

Table 10. Changes in fuel efficiency and carbon intensity of fuel

Q11: What do you think the share of each mode expressed in terms of tonne kms will be in 2020?	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Share of road	59.9	6.0	59.8	5.6	-6%
Share of rail	11.4	3.1	11.4	3.0	-4%
Share of inland waterway / coastal shipping	24.4	4.4	24.5	4.3	-2%
Share of pipeline	4.4	1.3	4.4	1.1	-10%

Table 11. Projected changes in freight modal split

Q12: How will the value, in real terms, of 1 tonne of product moved by the following modes to, from and within UK change by 2020? (where -2 = large decrease and 2 = large increase)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Road	0.4	0.9	0.5	0.8	-7%
Rail	0.4	0.8	0.5	0.7	-13%
Inland waterway / coastal shipping	0.1	0.7	0.1	0.7	-9%
Deep sea shipping	0.5	1.0	0.5	0.8	-14%
Airfreight	0.7	1.0	0.7	0.9	-9%

Table 12. Projected changes in value of goods transported by different modes

Q13: To what extent will the amount carried by rail by 2020 be influenced by the following factors? (where 0 = not at all and 4 = large extent)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Reliability	3.1	1.0	3.3	0.8	-24%
Speed	2.4	1.0	2.4	0.9	-11%
Congested rail infrastructure	2.9	1.0	3.0	0.8	-18%
Flexibility	3.0	0.9	3.1	0.8	-17%
Accessibility of terminals	3.0	0.9	3.0	0.7	-17%
Cost	3.0	1.0	3.1	0.9	-15%
Bureaucracy	2.5	1.1	2.6	1.0	-9%
Additional handling involved	2.6	1.0	2.8	0.9	-10%
Commodity mix	2.1	1.0	2.2	0.9	-7%

Table 13. Factors affecting the amount of cargo carried by rail

Q14: How effective would the following Government measures be in increasing rail's share of the UK freight market? (where 0 = no effect and 4 = very effective)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Upgrading rail infrastructure	3.1	0.9	3.1	0.8	-17%
Introduction of a road pricing scheme for HGVs	2.1	1.1	2.1	1.1	-1%
Expanding Freight Facilities Grant scheme	2.3	1.0	2.4	0.9	-10%
Revenue support for Channel Tunnel connections	2.2	1.1	2.3	0.9	-13%
Provision of dedicated rail freight routes	2.9	1.0	2.9	0.8	-14%
Promotion of best practice in company freight management	1.9	1.0	1.9	0.9	-9%
Planning policies for more effective co-ordination of transport modes	2.3	1.1	2.4	1.0	-9%
Higher duties on diesel fuel	2.0	1.1	2.1	1.0	-8%
Extending emissions trading scheme to freight transport	2.0	1.0	2.1	0.9	-12%
Enforcing regulations on road freight operators more rigorously	1.5	1.0	1.5	1.0	-5%
Simplifying administrative / regulatory framework for rail freight	2.2	1.0	2.3	1.0	-8%

Table 14. Efficiency of potential measures to increase rail's share of freight market

Q15: To what extent will the amount carried by coastal / short-sea shipping by 2020 be influenced by the following factors? (where 0 = not at all and 4 = large extent)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Reliability	2.6	1.1	2.6	1.0	-7%
Speed	2.4	1.1	2.4	1.0	-4%
Congested port infrastructure	2.6	1.0	2.7	1.0	-7%
Flexibility	2.5	1.1	2.6	0.9	-13%
Accessibility of ports	2.6	1.1	2.7	0.9	-16%
Cost	2.8	1.0	2.9	1.0	-6%
Bureaucracy	1.9	0.9	2.0	0.8	-13%
Additional handling involved	2.3	1.0	2.4	0.9	-9%

Table 15. Factors affecting the amount of cargo carried by coastal / short-sea shipping

Q16: How effective would the following Government measures be in increasing coastal / short-sea shipping's share of the UK freight market? (where 0 = no effect and 4 = very effective)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Upgrading port infrastructure	2.6	0.9	2.7	0.8	-12%
Introduction of a road pricing scheme for HGVs	1.8	1.0	1.8	1.0	-6%
Expanding Waterborne Freight Grant scheme	2.2	1.0	2.3	0.9	-15%
Promotion of best practice in company freight management	1.6	1.0	1.6	0.9	-9%
Planning policies for more effective co-ordination of transport modes	2.1	1.1	2.1	1.0	-7%
Higher duties on diesel fuel	1.7	1.1	1.8	1.0	-6%
Extending emissions trading scheme to freight transport	1.6	1.0	1.7	0.9	-8%
Enforcing regulations on road freight operators more rigorously	1.3	1.1	1.3	1.0	-1%

Table 16. Efficiency of potential measures to increase coastal / short-sea shipping's share of freight market

Q17: How are the constraints on using rail and shipping services likely to change by 2020? (where -2 = constraints significantly easing and 2 = constraints significantly tightening)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Railfreight services	-0.29	1.0	-0.32	0.9	-5%
Short-sea / coastal shipping services	-0.33	0.8	-0.34	0.7	-9%

Table 17. Projected changes in the constraints on using rail and shipping services

Q18: Please rate the likely importance of the following means of improving the fuel efficiency of freight transport operations by 2020 (where 0 = no importance and 4 = very important)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
Training schemes for fuel efficient driving	2.7	1.0	2.7	0.9	-8%
Higher fuel prices	2.4	1.2	2.6	1.0	-17%
Dissemination of best practice in fuel management	2.1	0.9	2.1	0.8	-9%
Out of hours' delivery operation	2.6	0.9	2.7	0.9	-8%
Information technology (telematics / vehicle routing software)	2.7	1.0	2.8	0.9	-8%
Vehicle design	2.8	0.9	2.9	0.8	-15%
Incentive schemes for employees	2.2	0.9	2.2	0.8	-9%
Improved vehicle maintenance	2.1	0.9	2.1	0.8	-3%
Engine performance	2.7	0.9	2.8	0.9	-8%

Table 18. Projected importance of fuel efficiency measures

Q19/20: To what extent has concern about climate change forced / will force your company to modify its freight transport operations? (where 0 = not at all and 4 = large extent)	Mean (round 1)	Standard deviation (round 1)	Mean (round 2)	Standard deviation (round 2)	Reduction of standard deviation
In last three years	2.0	1.2	2.1	1.1	-6%
By 2010	2.1	1.2	2.1	1.1	-7%
By 2015	2.6	1.0	2.6	1.0	-1%
By 2020	3.0	0.9	3.0	0.9	14%

Table 19. Impact of concerns about climate change on freight transport operations

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